FEBRUARY 1958

# THE WELDING JOURNAL

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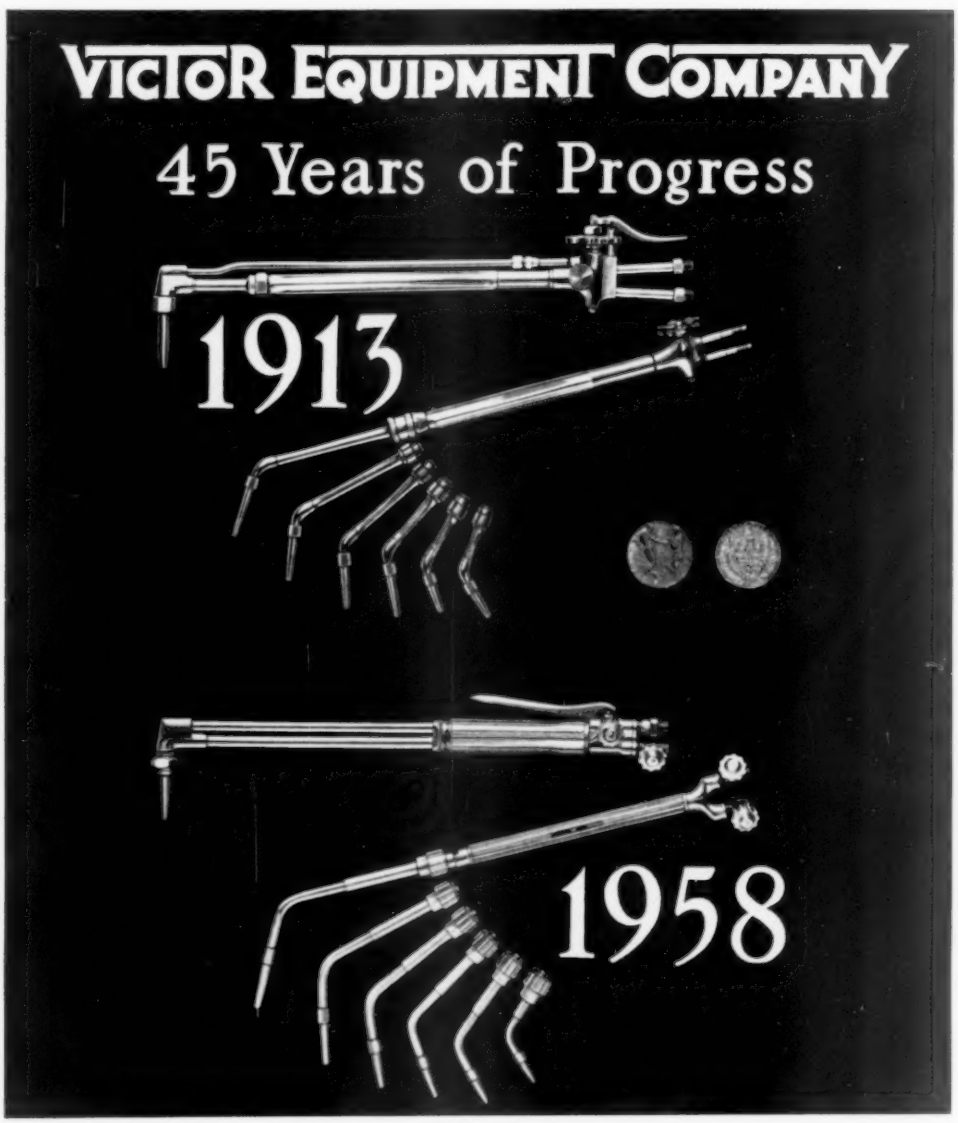


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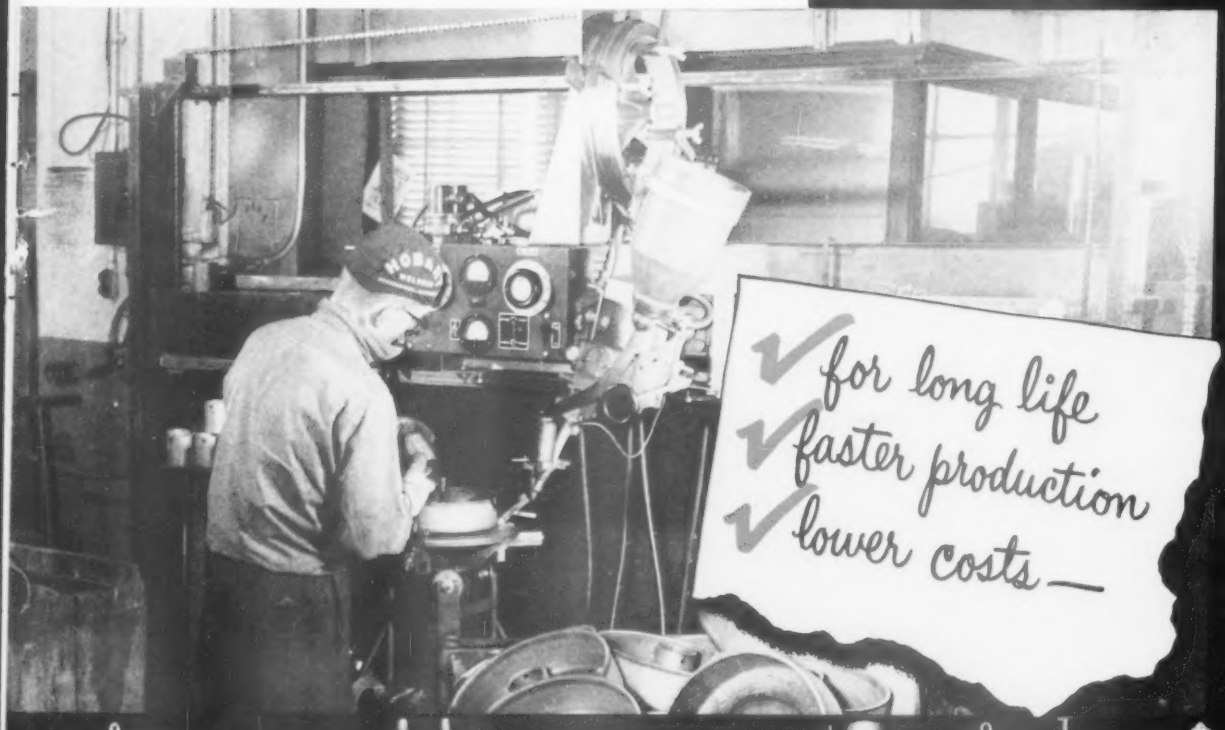


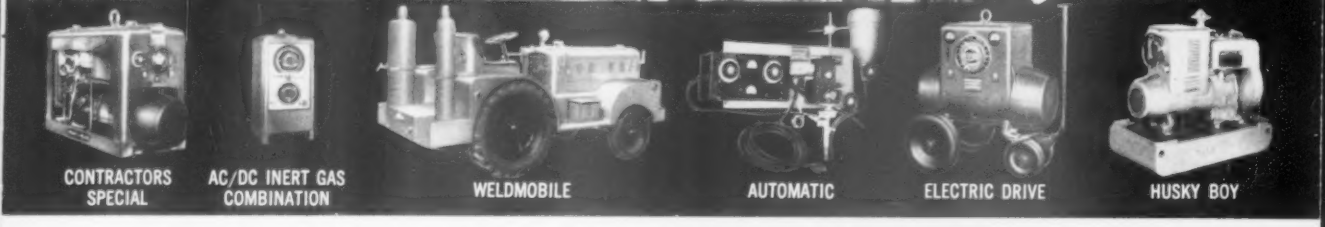

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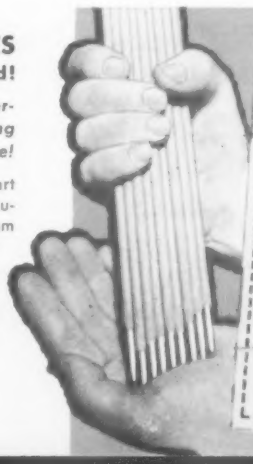

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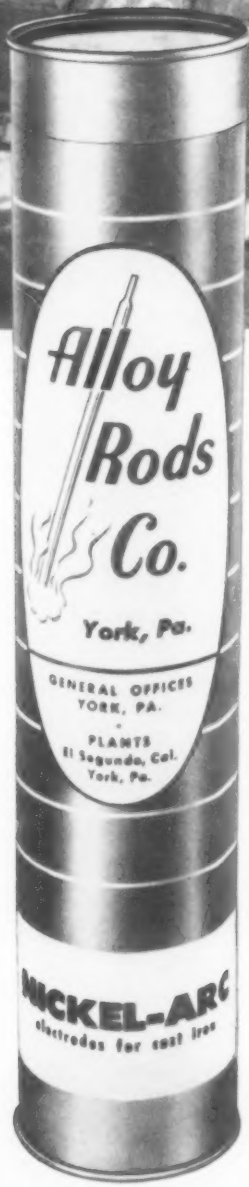


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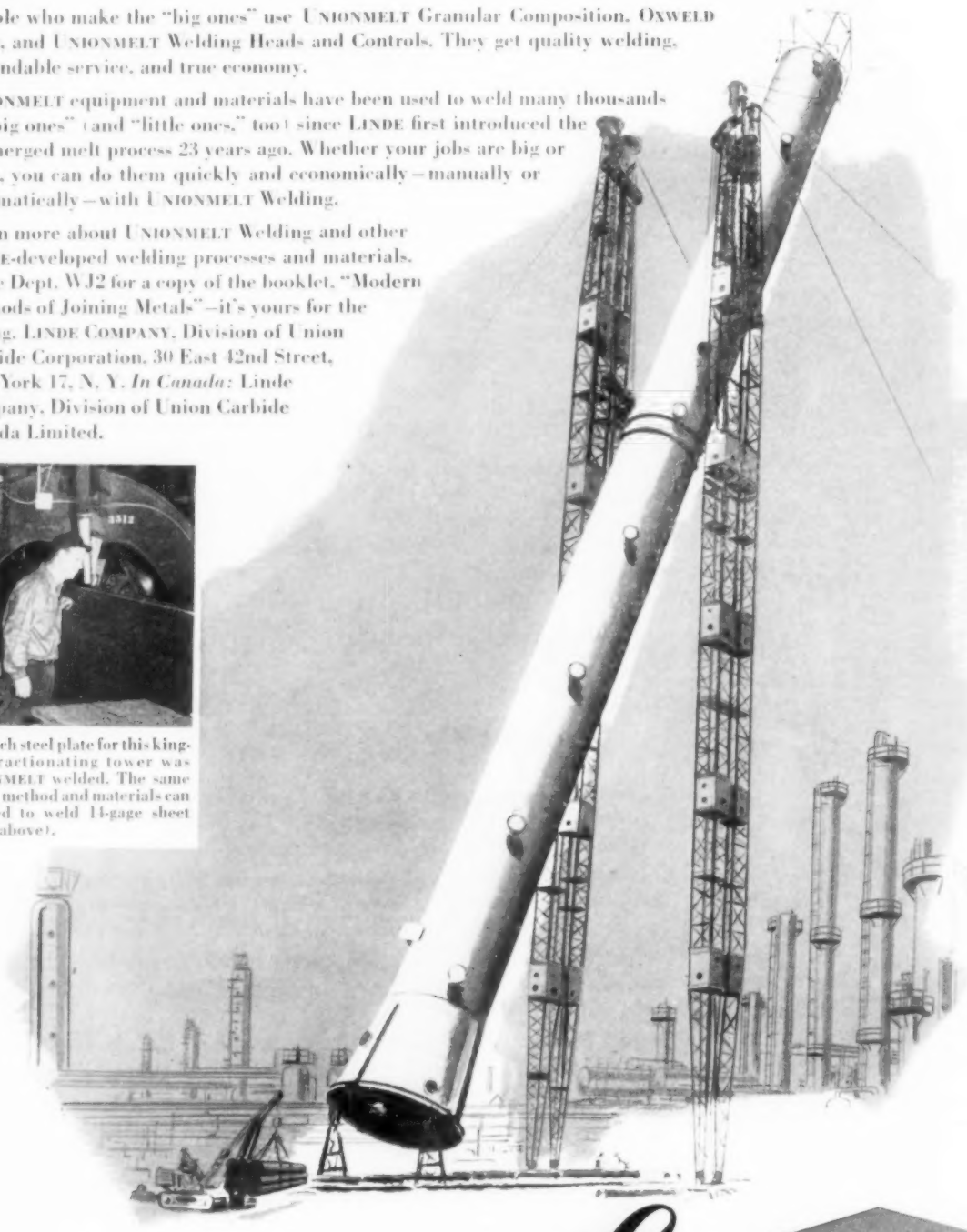

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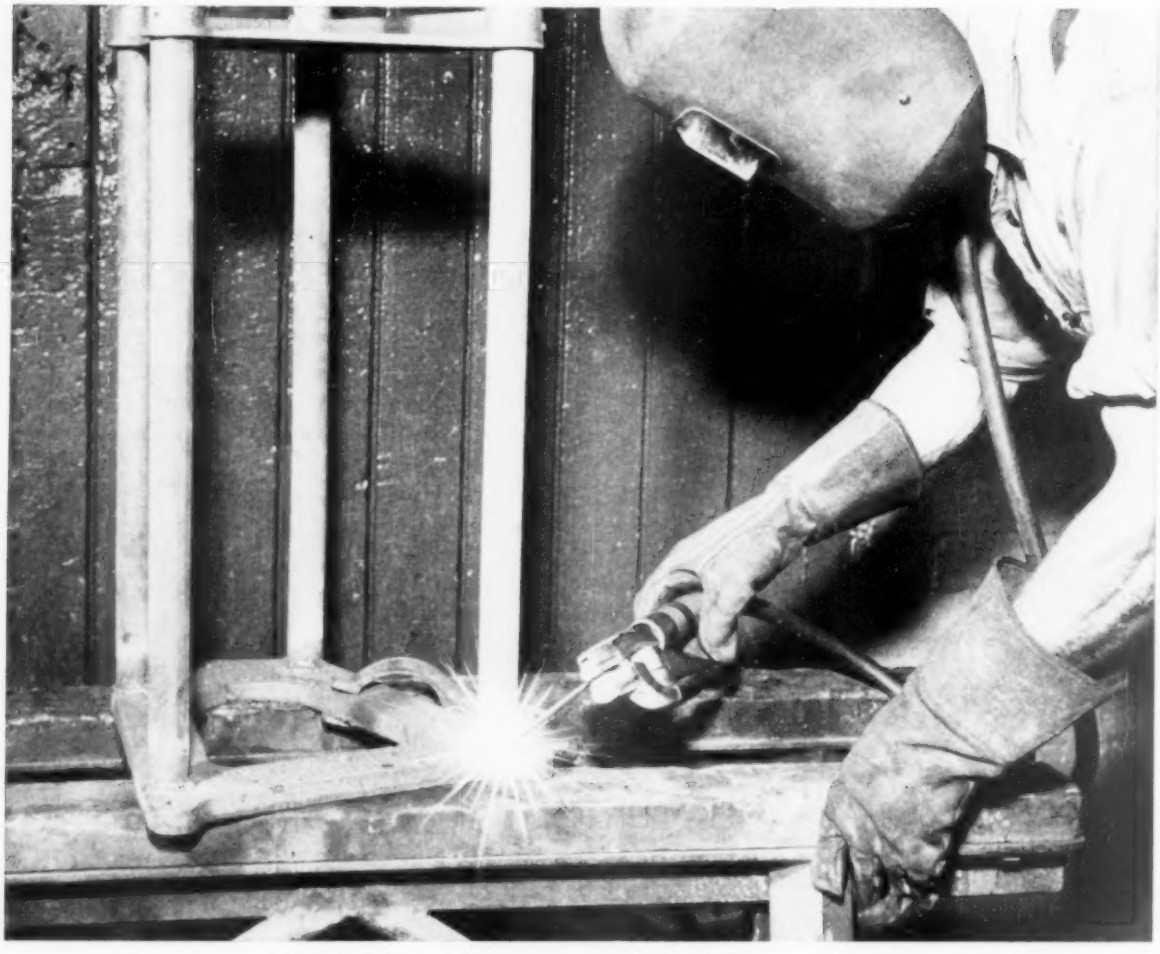

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## "IN TODAY ALREADY WALKS TOMORROW"

Almost 30 years ago, with the aid and advice of an AWS committee, I prepared an integrated history of the welding industry. Even then it was obvious that welding processes were beginning to provide a new series of joining techniques, and that these processes would lead to mechanization of assembly. Further, welding itself could be mechanized—about that the committee was cautiously optimistic.

Judged by developments since, that committee was modest—almost pessimistic. The years have brought new materials and alloys, closer tolerances and stricter requirements, new processes and automation. Welding and brazing were called upon to meet these greater needs; in meeting them they became two of the most mechanized and most common of assembly methods. Availability of welding and brazing inspired new materials and their prompt application. Many present-day products could not be made otherwise; many more could not be made to sell at a reasonable price. Nor could new processes be applied.

Developments have been coming thick and fast—witness any issue of THE WELDING JOURNAL. New industries, new materials, new products—all these are being served. The pace has become so fast, in fact, that there appears often to be time for little more than to spot the next objective. Therein lies danger.

Is the pace so fast that the long-term objectives may be missed? Industry after industry has found in recent years that it isn't enough to work from day to day. There must be a long-term plan, and perhaps an intermediate plan, as well as the obvious short-term goals.

Where should the welding industry, and your company, be in five, ten, twenty years? Do you have a reasonably clear picture of ultimate direction? Perhaps it is time for a realistic appraisal.

Unless each company in the welding industry is continuously evaluating these processes and their prospects, unless long-term objectives are spotted now and the necessary research and development work undertaken to attain them, welding may meet all current demands but be unprepared for future developments.

*E. J. Tangerman*
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# PERFORMANCE OF WELDS IN SOME ALUMINUM ALLOYS

*Data presented on welds in some of the aluminum alloys commonly considered for arc-welded construction*

BY PAUL B. DICKERSON

ABSTRACT. Development of the inert-gas-shielded arc-welding methods has brought significant improvements in the performance that can be obtained in aluminum welds. Because of these relatively new processes, additional aluminum alloys can now be welded satisfactorily and additional filler materials have come into use. Increased tensile properties with increased weld ductility can now be obtained with these new alloys.

This paper covers the strength and ductility of butt welds in various aluminum alloys, the longitudinal and transverse shear strengths of fillet welds, the effect of temperatures from −400 to 700° F upon the tensile properties, and the resistance to corrosion of several of the high-strength weldable alloys.

Also, until recent years, the principal methods for cutting aluminum have been limited to mechanical means. There has been a great need for a method of cutting that would give both the quality and versatility that the oxygen-cutting process exhibits for steel. The newly developed consumable-electrode and tungsten-electrode inert-gas cutting processes show great promise in overcoming this problem in the field of aluminum fabrication. The effect of these methods upon the metallurgy and weldability of the aluminum alloys is discussed.

**Paul B. Dickerson** is associated with Aluminum Company of America, New Kensington, Pa.

Presented to the American Welding Society Meeting at the Western Metal Congress, Ambassador Hotel, Los Angeles, Mar. 27, 1957.

## Introduction

Development of the inert-gas metal-arc welding processes has made welding a principal fabricating tool in the aluminum industry. Not only can aluminum now be considered "easy to weld" but, because of the paral-

lel advances in aluminum-alloy development, many new alloys and combinations of alloys can be joined by the inert-gas metal-arc welding methods. With these new alloys, higher as-welded strength with good ductility can be obtained.

Because the inert-gas welding processes can be used in all positions with relative ease and do not require the use of a corrosive flux, applications for welding aluminum have been widened tremendously. In addition, both the inert-gas tungsten-arc welding process and the semiautomatic inert-gas metal-arc (consumable-electrode) welding process are adaptable to mechanized operations. Advantages of mechanized welding include increased production, lower cost and improved quality.

The purpose of this paper is to present data on welds in some of the aluminum alloys commonly considered for arc-welded construction. The nominal compositions of these alloys are listed in Table 1.

## Strength and Ductility of Welds

Arc-welding processes produce a more highly concentrated heat than is the case with oxyacetylene or oxyhydrogen gas welding. As a result, less heat is dissipated into the weldment. This reduces the width of the heat-affected zone and the amount of distortion. The semiautomatic inert-gas metal-arc welding process is perhaps the fastest welding method and this minimizes the tendencies for weld cracking in some of the stronger alloys.

Since lower stresses are set up in the weldment by the more concentrated heat and faster welding speeds, alloys can now be employed as electrodes that were too crack sensitive to use as filler material with older welding methods. The use of 5154, 5356 and 5456 alloys as filler material provides increased weld ductility over that which was obtainable with 4043 (5% Si—balance Al) alloy filler wire. These filler metals also provide a better color match between the weld metal and base metal when the weldment is anodically treated. This is often important for architectural applications.

In addition, when welding the high-strength heat-treatable alloys, the consumable-electrode welding process has made possible the use of base alloy as filler material. This provides the most homogeneous structure and best tensile properties that can be obtained.

The average tensile strength and free-bend elongation for aluminum alloys best suited to welding are shown in Figs. 1 and 2.

These data summarize the results of several thousand tests made during the last ten years. The results include welds made with both the tungsten-arc and the consumable-electrode welding processes. The tensile results represent both reduced- and full-section specimens. Ductility, as represented by the free-bend elongation, is measured on the weld in accordance with the standard AWS test.

Relatively few tests have been made on alloys 5456, 2014, 2024 and 7075, so that additional tests may necessitate slight changes in the values given.

Following are the results of data obtained thus far:

1. Welds in nonheat-treatable alloys can be made that develop the full strength of the alloys in the annealed condition.

2. The highest strength welds in the nonheat-treatable alloys are obtained in 5456 alloy.

3. When the weldment can be heat treated and artificially aged after welding, a substantial increase in the tensile strength can be achieved, but ductility as measured by free-bend tests is lowered.

4. When welding 6061-T6 alloy, better ductility is obtained with 5154 than with 4043 filler material with or without post-weld heat treatment.

5. Heat treating and artificially aging 6061 after

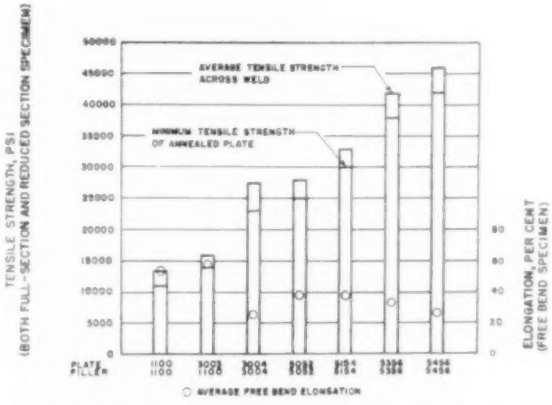


Fig. 1 Strength and ductility of butt welds in non-heat-treatable aluminum alloys

Table I—Nominal Compositions of Wrought Aluminum Alloys

| | | Element, % | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Alloy* | *Al* | *Cu* | *Si* | *Mn* | *Mg* | *Cr* | *Zn* | *Ti* |
| 1100 | 99.0 min | .. | .. | .. | .. | .. | .. | .. |
| 3003 | Remainder | .. | .. | 1.2 | .. | .. | .. | .. |
| 3004 | Remainder | .. | .. | 1.2 | 1.0 | .. | .. | .. |
| 5052 | Remainder | .. | .. | .. | 2.5 | 0.25 | .. | .. |
| 5154 | Remainder | .. | .. | .. | 3.5 | 0.25 | .. | .. |
| 5356 | Remainder | .. | .. | 0.12 | 5.0 | 0.12 | .. | 0.13 |
| 5456 | Remainder | 0.1 | .. | 0.8 | 5.25 | 0.1 | .. | .. |
| 6061* | Remainder | 0.25 | 0.6 | .. | 1.0 | 0.25 | .. | .. |
| 2014* | Remainder | 4.4 | 0.8 | 0.8 | 0.4 | .. | .. | .. |
| 2024* | Remainder | 4.5 | .. | 0.6 | 1.5 | .. | .. | .. |
| 7075* | Remainder | 1.6 | .. | .. | 2.5 | 0.3 | 5.6 | .. |

* Heat-treatable alloys.

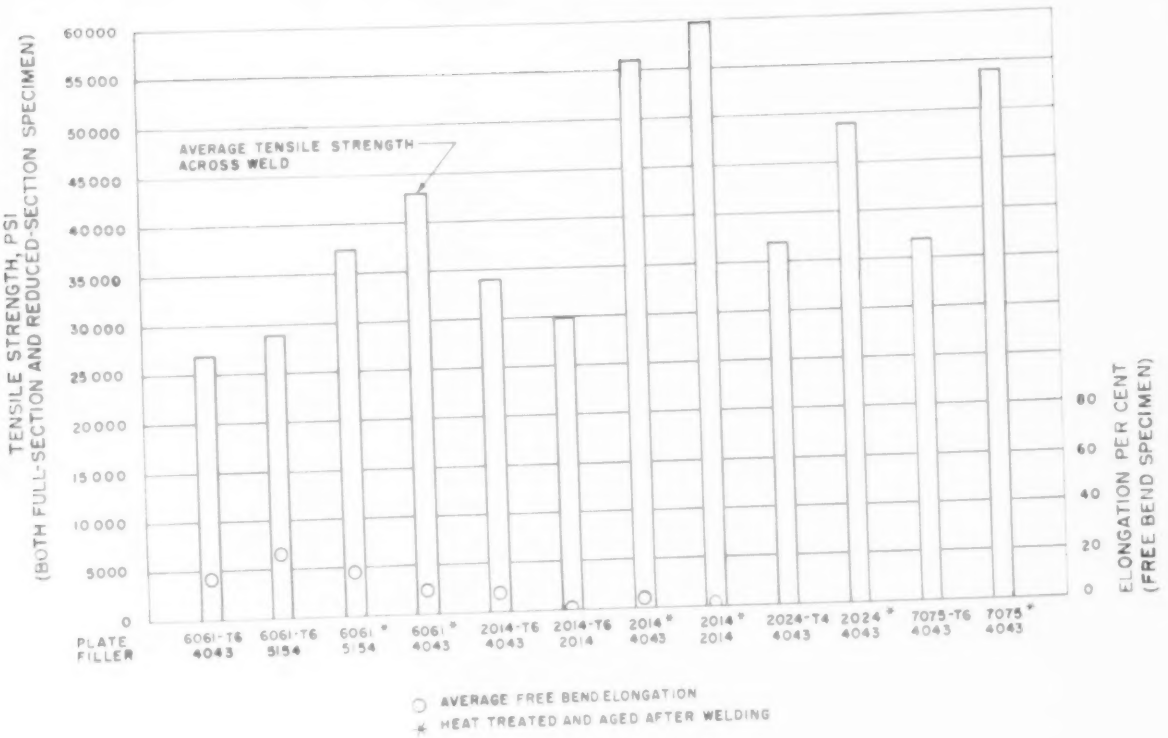


Fig. 2 Strength and ductility of butt welds in heat-treatable aluminum alloys

welding develops the full strength of 6061-T6 across the welds made with 4043 filler wire.

6. Welds in 2014, 2024 and 7075 alloys show high strength after post-weld heat treatment but cannot be counted on to develop 100% joint efficiency. Little commercial welding is done with these alloys because of low ductility in the weld zone.

Whenever aluminum alloys are are welded, the temperature in the base metal adjacent to the weld is sufficient to anneal the base material. The extent of this softening is dependent upon (1) the speed of welding, (2) the welding technique or procedure and (3) the thickness of the material.

In the case of the nonheat-treatable alloys, the as-welded properties can be increased only by work hardening the heat-affected area. This is seldom feasible; consequently, most design values in the work-hardenable alloys are based upon the annealed properties of the base metal.

When considering the heat-treatable alloys, however, the heat-affected zone will not reach the fully annealed state. It can be noted that the minimum tensile strength of welds in 6061-T6 is 50% greater than the tensile strength of 6061-O. Rapid welding and rapid weld cooling results in stronger joints than slow welding and a slow cooling rate. When allowing the joint to cool naturally in air, the metal thickness influences the strength of the weld. The values given in Fig. 2 are average for comparison of the various heat-treatable alloys.

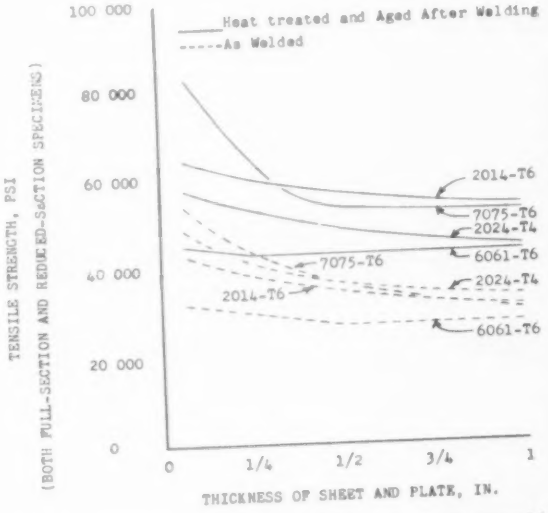


Fig. 3 Strength of butt welds in four heat-treatable aluminum alloys

Other factors that make weld strength a function of the metal thickness are size of the weld and sensitivity of weld metal to heat treatment. The reinforcing effect of the stronger base metal on the weld zone is higher in thin material than in thick material. The influence of these factors on weld strength can be seen in Fig. 3.

This shows that there is a significant difference in the

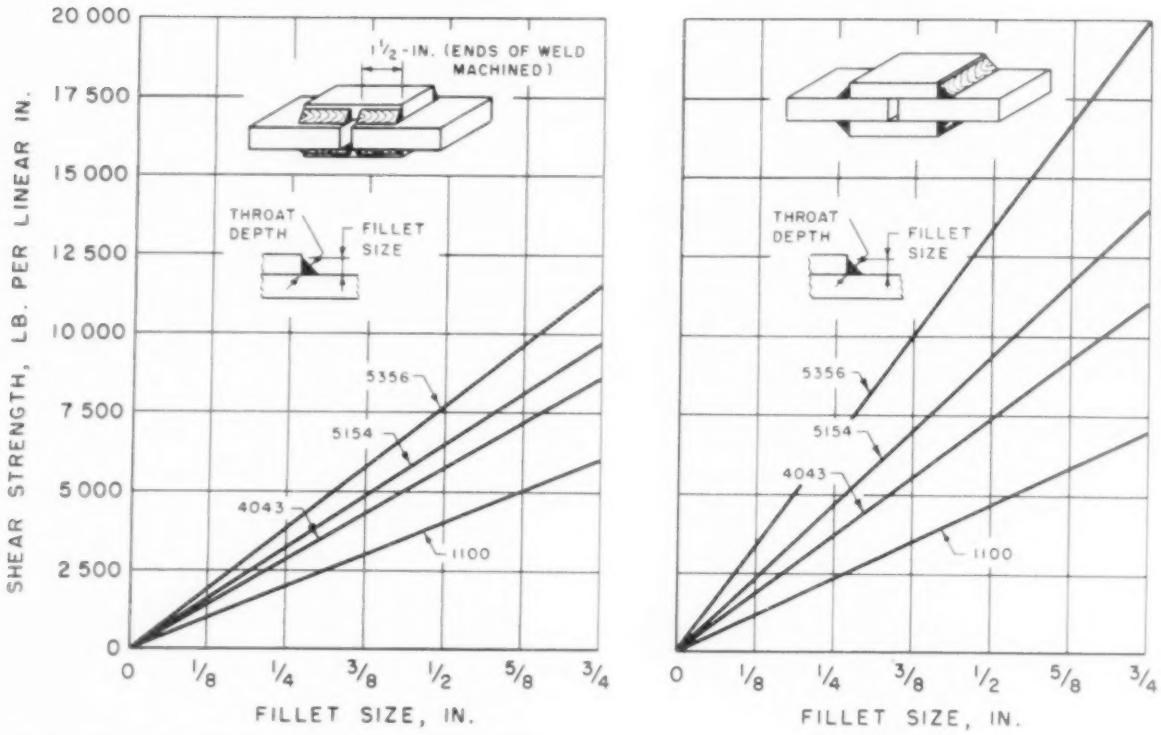


Fig. 4 Longitudinal and transverse shear strength of fillet welds

Fig. 5 40-gal capacity, 5154 alloy drums filled with water and dropped 30 ft

strength of arc welds in various thicknesses of the heat-treatable alloys up to 1 in.

## Other Mechanical Properties

The shear strength of fillet welds (Fig. 4) loaded longitudinally and transversely has been established by tests and is a function of the composition of the filler alloy. These values indicate the strength for a symmetrical specimen; bending was avoided during testing. Unit strengths are expressed in terms of measured throat depth—not nominal weld size.

Dropping a loaded vessel from a height to induce substantial distortion in the assembly is one method of determining the performance of a weldment. Figures 5 and 6 illustrate the ductility of welded aluminum-magnesium alloy tanks in such tests. The tanks in Fig. 5 are 40-gal gasoline test tanks, which are 20 in. diam by 31½ in. long, fabricated of 5154 alloy in thicknesses of 0.102, 0.125 and 0.160 in. They were filled with water to a weight equivalent to a tank full of gasoline and dropped from a height of 30 ft. No rupture of the drums occurred. Figure 6 shows a 21-gal drum of 0.204-in. thick 3004 alloy which was filled

Fig. 6 21-gal capacity, 0.204-in. wall, 3004 alloy drum filled with water and dropped 9½ ft onto concrete filled steel pipe

Fig. 7 ¼-in. wall, 5154 aluminum-alloy pressure vessel hydrostatically tested to destruction. Note typical failure adjacent to the weld in the heat-affected zone

with water and dropped 9½ ft onto a 6-in. steel pipe filled with concrete. The weld hit directly on the steel pipe; again no fracture resulted.

Hydrostatically testing a fabricated vessel to the point of destruction is another method employed to determine the validity of a design, welding procedure or choice of material. Figure 7 illustrates the type of test vessel used by the author's company to provide proof of the strength characteristics of various alloys.[1] These destruction tests in the nonheat-treatable alloys have shown the strength of the welded joints to be at least equal to the specified minimum tensile strength of annealed plate.

## Effect of Temperature

As temperature is elevated, aluminum alloys exhibit a reduction in strength. As temperature is decreased below room temperature, however, aluminum shows no loss in properties. In fact, at sub-zero temperatures aluminum becomes stronger. Figure 8 gives the tensile properties of welds in five commonly welded alloys at temperatures from −400 to 700° F. The curves for alloys 3003, 5052, 5154 and 6061 are the results of tests after 10,000 hr at temperature. The values for 5356 are tentative since the results are based upon only 1000 hr at temperature. The tensile strength across the weld in the nonheat-treatable alloys is equal at all temperatures to that of the unwelded annealed base metal. No loss in weld ductility of sub-zero temperatures is encountered in these nonheat-treatable alloys. For alloy 6061 welded with 4043 filler wire and heat treated and aged after welding, the tensile strength at all temperatures is equal to that of the base metal with no loss in ductility at sub-zero temperatures. The tensile strength of welded 6061 with no subsequent heat treatment increases at about the same rate as that of 6061-T6 plate as the temperature is lowered to −320° F. As the temperature is raised above room temperature, the strength across the weld decreases at a lesser rate than that of the base metal until, at 500° F, the strength of the weld equals that of the base metal.

## Resistance to Corrosion

Aluminum-magnesium alloys, such as 5052, 5154 and 5456, generally display excellent resistance to corrosion. This is true for these alloys as the principal components or as filler materials for other alloy components, and refers particularly to applications at atmospheric temperatures or below.

For installations involving prolonged elevated temperature service (above 150° F), limitations are placed

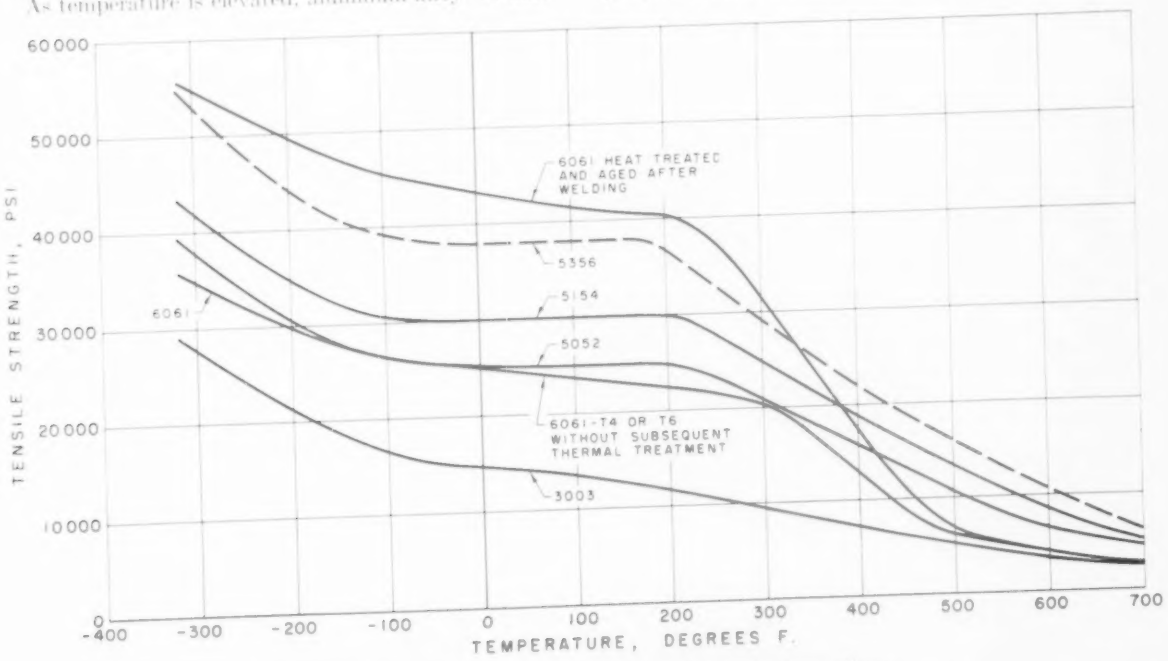


Fig. 8 Minimum tensile strengths at various temperatures across butt welds in aluminum alloys

Fig. 9 Arc cutting hole for fitting in railroad tank car dome

on the use of aluminum alloys with the higher magnesium levels because of their tendency toward decreased resistance to corrosion and stress corrosion. Based on present knowledge, the resistance to stress corrosion of the aluminum-magnesium alloys is a function of several factors: magnesium content, percent of cold work, temperature, time at temperature, environment, nature and magnitude of stresses. Alloys with magnesium at the level used in 5052 alloy have been found suitable for elevated temperature service. Research is being continued to determine under what conditions of composition and temper the higher aluminum-magnesium alloys can be used for elevated temperature service. At present, for applications of these alloys at temperatures above 150° F, it is suggested that the aluminum producer be consulted.

Magnesium-silicide type aluminum alloys, such as 6061 and 6063, have a high resistance to corrosion in the unwelded and welded condition, and are not noticeably affected by such factors as temper, temperature operation, nature and magnitude of stresses and environment.

The resistance to corrosion of welded assemblies in 2014, 2024 and 7075 alloys, both bare and clad, has been evaluated in accelerated and natural environments. Results have shown that the metal thickness, composition of the filler alloy, or method of welding do not greatly affect their corrosion resistance. Solution heat treating and artificially aging these alloys after welding improves the corrosion resistance to the greatest extent. If the assembly cannot be reheat-treated and aged after welding, then better resistance to corrosion is observed if the original material is welded in the -T6 temper rather than the -T4 temper. The corrosion resistance of welded alclad material is superior to that of welded non-clad material. Paint protection is recommended when welded joints of these non-clad alloys are employed in outdoor environments.

## Design Rules

A number of code-writing bodies have prepared design rules for the use of the aluminum alloys for various applications. These include:

1. Boiler and Pressure Vessel Code Committee of

the American Society of Mechanical Engineers.[2,3]

2. American Petroleum Institute.[4,5]
3. American Society of Civil Engineers.[6]
4. American Standards Association.[7]
5. Association of American Railroads.[8]
6. Interstate Commerce Commission.[9]
7. National Fire Protection Association.[10]

These specifications include alloys that are pertinent to that field. Work is in progress to keep these specifications up to date. In addition to design values, the methods of inspection, testing procedures, qualification requirements and quality standards are given.

## Arc Cutting

Of related interest to the field of arc welding are two processes recently developed for arc cutting aluminum. One method employs standard semiautomatic inert-gas metal-arc (consumable-electrode) welding equipment, but a mild steel electrode is used. The second process is a modification of the inert-gas tungsten-arc welding process. The fundamental difference is the fact that a restricted gas orifice is used with a gas mixture of argon and hydrogen.

Both arc-cutting processes are versatile and suited to either manual or mechanized operation. The quality of the cut produced is good and, in most cases, is suitable in the as-cut condition for further processing, such as welding. These two arc-cutting methods appear to have a great future in aluminum fabrication, and will, most likely, be used for parallel purposes and in a similar manner as oxyacetylene cutting is employed in the steel industry.

The immediate application for inert-gas metal-arc cutting has been in the tank and pressure-vessel field for cutting holes for fittings. Figure 9 shows its use on a railroad tank car. The equipment can be adapted to standard tracing apparatus and can be used for stack cutting, beveling and similar operations.

Metal thicknesses ranging from $^1/_8$ to 3 in. have been arc cut. As in welding, there is a narrow heat-affected zone created immediately adjacent to the section on which the arc impinges. The surface of the cut has been melted and consequently has a cast structure. The total thickness of these zones is less than 0.100 in.

Because of the intensity of the cutting arc, a high temperature differential exists in the material during the cutting operation. This differential sets up stresses at the cut edge which create a metallurgical problem in the heat-treatable alloys. Both surface and intergranular cracking have been observed in all heat-treatable alloys regardless of temper. This condition is illustrated in Figure 10 and could be a potential stress raising or corrosion hazard in service. The maximum depth of cracking observed in the heat-treatable alloys at the present time is 0.080 in. If this condition is undesirable, a shallow chipping or machining should be used to eliminate the cracks. This condition has not been observed in any of the nonheat-treatable alloys.

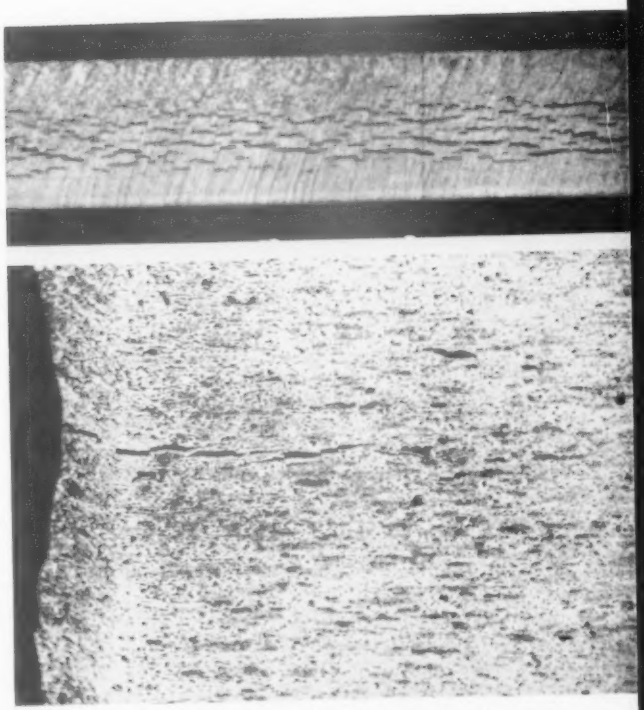

Fig. 10 Top: Face of arc cut in heat-treatable aluminum alloy, magnified X 3. Bottom: Cross section of arc cut heat-treatable alloy showing melted zone and heat-affected zone, magnified X 100. Reduced $^1/_3$ upon reproduction

Welding over inert-gas metal-arc cut edges in the as-cut condition has been performed very satisfactorily. Radiographic examination, as well as tensile and bend tests on these welds, has shown no difference in results as compared with welds made on mechanically prepared surfaces.

*Acknowledgment*

The author wishes to acknowledge the assistance of personnel of the Alcoa Research Laboratories during the preparation of this paper. They compiled most of the data presented in it.

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# METAL SPRAYING IN INERT ATMOSPHERES

*A workable system for producing metallic coatings by metal-arc spraying in inert atmosphere is reported upon by the authors*

BY R. E. MONROE, D. C. MARTIN AND C. B. VOLDRICH

ABSTRACT. A new and promising method of producing metallic coatings, by metal-arc spraying in inert atmospheres, was studied. Zirconium coatings were deposited on uranium by this method. These coatings were porous and contained many spray particles which were not satisfactorily flattened out during deposition. A diffusion heat treatment after spraying was effective in eliminating the boundaries between individual zirconium particles. As-sprayed and heat-treated zirconium coatings had good adhesion to uranium. However, the study of zirconium spraying on uranium was discontinued, since other methods of coating investigated in other studies were more feasible.

## Introduction

Protection of uranium from corrosive attack in water has been a constantly studied problem. Work initiated in 1952 to produce thin corrosion-resistant alloy layers on Hanford fuel elements included a program to study coating of uranium by metal spraying in inert atmospheres. Zirconium coatings were deposited on uranium with equipment developed for arc spraying in inert atmospheres. These coatings were very porous and could not be materially improved by subsequent diffusion heat treatments.

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Work conducted under AEC Contract W-7405-eng-92.

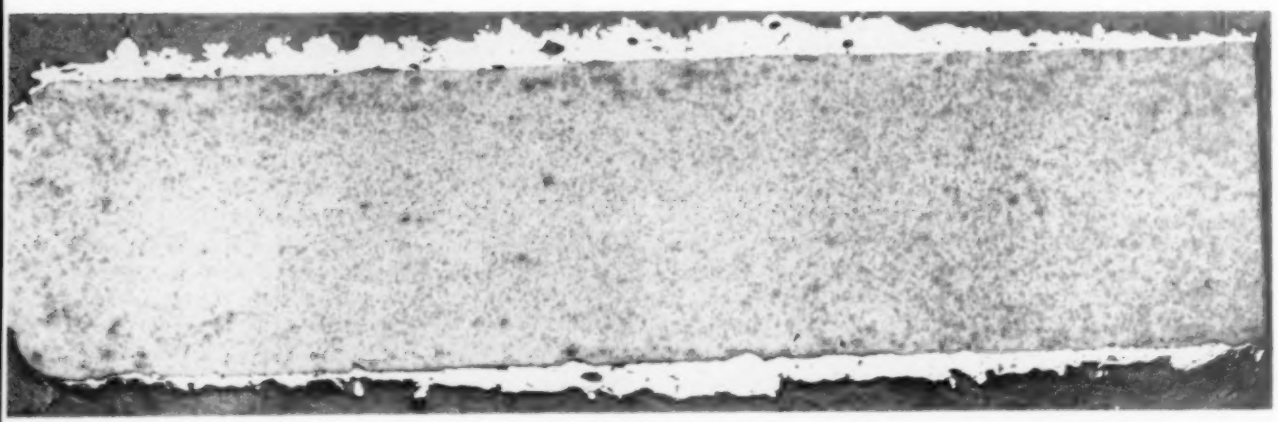
This work was discontinued in 1953* because developments with other coating methods were more satisfactory for the Hanford application. The progress made with metal spraying in inert atmospheres was encouraging, but tests of actual coated specimens were just beginning when the work was terminated.

Much of this report covers the development of arc-spray equipment suitable for use in inert atmospheres. With this equipment, metals such as molybdenum, titanium and zirconium can be sprayed in a protective atmosphere without harmful contamination from oxygen or nitrogen. Operation of the arc-spray equipment is discussed in detail, since the properties of the sprayed metal deposits are largely determined by the operating characteristics of the equipment.

## Summary

To produce a useful metal spray, there must be some method of supplying a small but continuous supply of molten metal and a high-velocity gas stream arranged to atomize and propel this metal. Equipment utilizing an oxy-fuel gas flame to melt the metal and compressed air to spray it cannot be used to produce uncontaminated

* Publication delayed for declassification.



As polished uranium air etched

Fig. 1 Zirconium coating on uranium, as sprayed, X 8. Coating thickness: Top—0.004–0.038 in.; Bottom—0.004–0.030 in.

coatings of metals susceptible to contamination by oxygen and nitrogen. To produce a coating free of contamination by these gases, the melting, atomization and propelling must occur in an inert atmosphere. The methods listed below were considered for producing metal sprays in inert atmospheres. (1) An arc between two consumable electrodes fed through a high-velocity gas blast, (2) induction melting of a wire or tube with a suitably arranged gas blast, and (3) an arc between two disks of the coating metal rotated at high speeds.

The first of these methods appeared to be the most promising and to offer the quickest means of evaluating sprayed coatings, since commercial equipment was available. However, studies made with this equipment showed that it could not be adapted for inert-atmosphere work. Arc-spray equipment suitable for use in inert atmospheres was developed and used in the remaining work. Operation of this equipment was good for spraying stainless steel but was only fair with zirconium.

Molybdenum, titanium and zirconium were considered as possible coating materials for uranium. Previous studies of alloys of these metals and uranium indicated that zirconium coatings would be superior to coatings of molybdenum or titanium. Therefore, only zirconium coatings on uranium have been studied. Preliminary tests were made using stainless-steel wire and mild-steel plate in place of zirconium and uranium, respectively.

Flat uranium plates were sprayed with zirconium, using the arc-spray equipment in an argon atmosphere. Figure 1 shows a transverse section cut from a sprayed specimen. The coatings contained considerable porosity and some spray particles which were not deformed during deposition. Further work toward improving the operation of the arc-spray equipment when using zirconium should eliminate the porosity and produce a consistently fine spray.

Diffusion heat treatments of sprayed specimens were made in attempts to form a corrosion-resistant surface alloy of uranium and zirconium. The coatings of heat-treated specimens were not much better than the as-sprayed coatings. Compacting the coatings by rolling, peening or pressing before heat treating appears necessary, unless porosity-free coatings can be deposited. Compacted coatings should be more responsive to heat treatment.

## Spraying Equipment

Only one commercial metal-spray pistol utilizes an arc for melting the metal to be sprayed. One of these pistols was obtained from Switzerland for use in this investigation. Difficulties in adapting the pistol for use in inert atmospheres led to the development of new arc-spray equipment. This equipment was designed and constructed specifically for use in inert atmospheres.

During tests in inert atmospheres, the metal-spray equipment was operated in a vacuum-purged chamber provided with high-pressure gas and electrical connections. Gas for atomizing and propelling the spray was

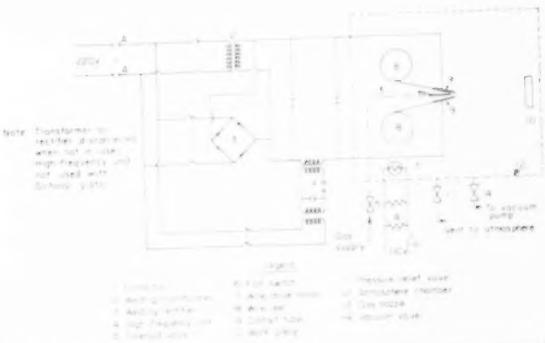


Fig. 2 Schematic diagram of metal-spray equipment and electrical circuit

Fig. 3 Electric pistol

supplied from commercial cylinders. The spraying chamber was provided with a pressure-relief valve to maintain a low positive pressure during operation. A closed system utilizing a compressor to recirculate the gas through the spray equipment would be more economical and would purify the gas through its continued use. A schematic diagram of the metal-spray equipment is shown in Fig. 2.

### *Commercial Spray Pistol*

The arc spray pistol is similar to other metal-spray guns designed for manual spraying, except for the use of an arc rather than a flame to provide molten metal. A view of this pistol is shown in Fig. 3. Two wires are fed through the pistol by a gas-turbine-driven gear train. The wires are guided together inside a gas nozzle connected to a supply of compressed gas. A voltage difference is applied between the wires to form an arc, and the high-velocity gas stream passing through the nozzle atomizes and propels the metal melted in the arc.

Despite several modifications, spraying studies in inert atmospheres with the commercial equipment were ham-

pered by unsteadiness of the arc, because of the lack of oxygen in the inert atmospheres. In normal operation, compressed air is used with the arc-spray pistol and arc stability is fairly good.

### *Inert-Gas Arc-Spray Equipment*

After using the commercial pistol in an inert atmosphere for some time without success, new arc-spray equipment was designed and built specifically for use in inert atmospheres. This equipment was designed to allow studying of as many of the variables in the spray process as possible.

The equipment consists of two wire-drive units which can be positioned to vary the included angle between the electrode wires from 0 to 180°. Wires are fed through the drive mechanism and contact tubes with-

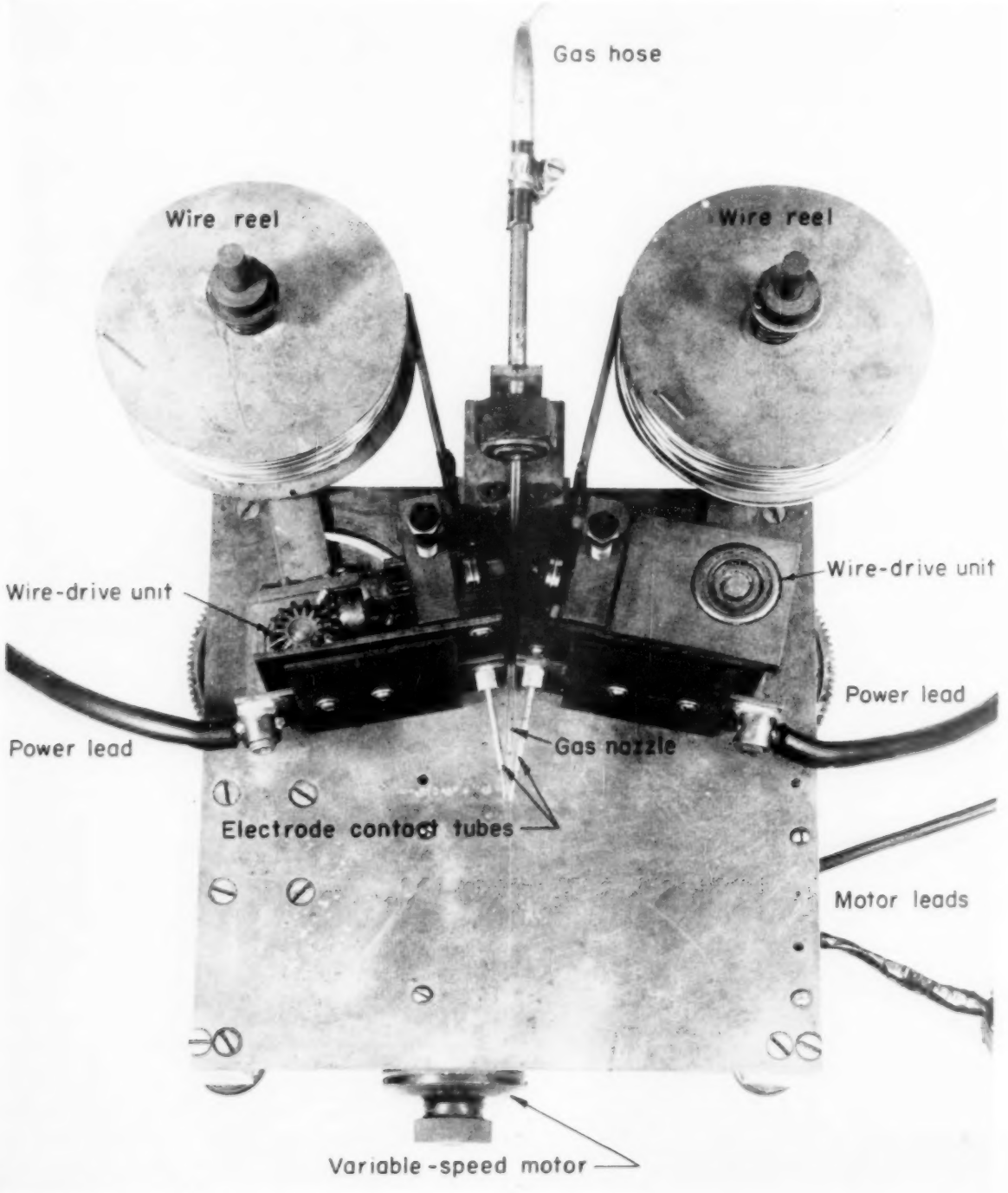



Fig. 4 Arc-spray equipment

out bending after they leave the wire reels. Addition of a wire straightener can be made if it should be necessary in spraying any particular metal. The drive units are driven by a single variable-speed motor to insure even feeding of the two wires. The wire-feed speed can be varied from 110 to 400 ipm with the present gear train. Higher speed ranges can be obtained by changing the gear train between the wire-drive units and the motor. Standard-wall pyrex tubing positioned between the two contact tubes is used to supply the high-velocity gas stream. Other types of gas nozzles also may be used. Either alternating or direct current with superimposed high frequency are used to supply power to the arc. Figure 4 shows the top view of the arc-spray equipment.

## Experimental Work

Preliminary metal-spray tests were made using stainless-steel wire. The purpose of these tests was to determine the range of operating conditions for the pistol and arc-spray equipment and the effect of varying those conditions. Once these conditions had been established, zirconium was sprayed onto uranium.

### *Exploratory Tests Using Stainless Steel*

Initial tests were made using $^1/_{16}$-in. diameter stainless-steel wire, compressed air and the commercial electric pistol. A steady spray could not be obtained when using alternating current. With direct current, good sprays were obtained at times, but consistent results were not obtained, even after modifications had been made to improve the gun performance. Although exhaustive tests were not made, the temper of the wires appears to greatly affect the performance of the commercial pistol. Soft wires were easier to feed through the pistol. However, the biggest drawback to this equipment is the lack of sufficient insulation to permit the use of a high-frequency circuit for stabilizing the arc.

The arc-spray equipment was designed so that the effects of the variables listed below could be studied.

| *Variable* | *Controlled by* | *Changes* |
|---|---|---|
| Momentum of gas stream | Nozzle diameter, gas pressure, and gas density | Particle size and velocity |
| Included angle | Selection | Shape of spray |
| Location of gas jet | Selection | Shape of spray |
| Power source | Selection | Arc stability |
| Arc length* | Wire-feed speed | Burn-off rate and particle size |
| Arc voltage* | Arc length, metal vapor present in arc, and atmosphere | Burn-off rate and particle size |
| Current* | Power-source setting | Burn-off rate and particle size |
| Surface condition of wire | Cleaning and thin coatings | Unknown |
| Electrical and magnetic forces in the arc | All other factors listed and properties of metal being used | Unknown |
| Wire diameter | Selection | Burn-off rate and particle size |

*Variable cannot be changed without some change in the others.

A complete evaluation of all of these variables was not made before this work was terminated.

With the arc-spray equipment, steady sprays were obtained with either alternating or direct current. When using alternating current, spray was thrown off erratically, probably because of explosions occurring during reignition of the arc. Use of direct current with superimposed high-frequency current resulted in the steadiest arcs and sprays. Stability of the arc seemed to indicate a good spray. The conditions tabulated below were found to produce the finest sprays and the steadiest arc when using $^1/_{16}$ in. diam. Type 304 stainless-steel wire and compressed air:

| | |
|---|---|
| Current | 230 amp |
| Arc voltage | 37 v |
| Wire speed | 200 ipm |
| Included angle | 25 deg |
| Nozzle diameter | 3 mm (0.118 in.) |
| Air pressure | 70 psi |

Tests were made to determine the effect of changes in these settings. Coarser sprays were obtained with higher arc voltages, larger diameter nozzles, and lower currents, wire speeds, and gas pressures. At a given current setting on the power source, changes in the wire-feed speed caused proportional changes in the current directly and in the arc voltage inversely. Included angles from 20 to 30 deg were satisfactory for spraying. Included angles of 90 and 120 deg were not satisfactory.

One characteristic of the arc-spray equipment which caused some experimental difficulties was the extremely high burn-off rates necessary to obtain arc stability. However, this characteristic could be used to advantage in applications where large areas require coatings.

## Zirconium-Spray Coatings on Uranium

Spraying of uranium with zirconium was begun when satisfactory sprays were obtained with the arc-spray equipment. Stability of the arc when using zirconium in an atmosphere of argon or helium was less than when using stainless steel in air.* Improvements in the arc stability will be necessary to deposit uniform zirconium coatings on uranium.

### *Specimen Preparation and Spraying*

Specimens to be coated were $1^1/_2$- x 2-in. rectangles and were sheared from $^1/_4$-in. thick hot-rolled uranium plate. A 10% nitric acid pickle followed by grit blasting immediately before loading into the atmosphere chamber was used to prepare the specimens for spraying. Other methods of preparing the specimens for coating did not appear so satisfactory as this procedure. Low hafnium-zirconium wire, $^1/_{16}$ in. in diam., was used for the consumable electrodes.

After the arc-spray equipment and specimens for coating were in place, the atmosphere chamber was sealed and evacuated to a pressure 100 microns of mercury. The chamber was then filled with argon or

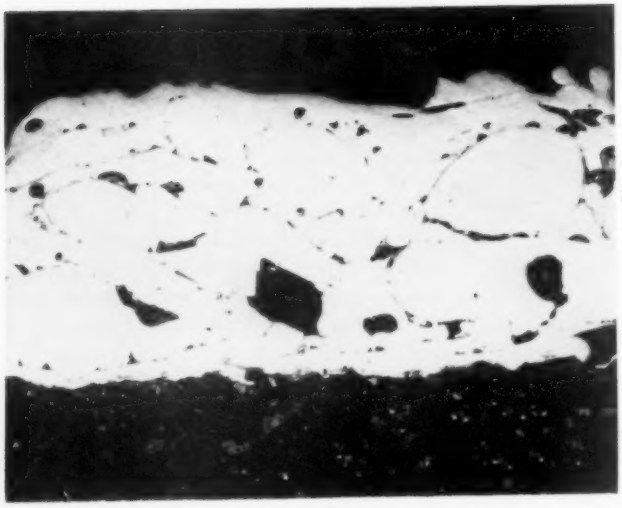
*Spray tests made with aluminum, copper, nichrome and Elgiloy in various atmospheres have also resulted in arcs which are more stable than the arc formed with zirconium.

helium. Argon was preferred for spraying because of its higher density. Some contamination of the zirconium was expected from nitrogen present in the argon.

The uranium plates were placed directly in front of and 6 in. away from the arc. Coatings were deposited at times ranging from 0.05- to 0.24-min arc time. The conditions used for spraying with zirconium in argon using direct current with superimposed high frequency were as follows:

| | |
|---|---|
| Current | 240 amp |
| Arc voltage | 35 v |
| Wire-feed speed | 340 ipm |
| Included angle | 22½ deg |
| Nozzle diameter | 4 mm |
| Gas pressure | 85 psi |

X 250 As polished




X 75 $CH_3O$, $HNO_3$, HF etch

Fig. 5 Zirconium coating on uranium, as sprayed

### Heat Treatment

Even the best metal-sprayed coatings may not form a continuous protective layer. However, a continuous protective layer is considered necessary for uranium, since extremely reliable coatings are desired. Metal-sprayed coatings would be useful, if diffusion of zirconium at the coating uranium interface could be obtained, thereby forming a continuous corrosion-resistant zirconium-uranium-alloy layer.

Coated specimens were heat treated in a vacuum of 10 microns of Hg or better. The three heating cycles given in the tabulation below were used:

| *Temperature, °F* | *Time at temperature, hr* | *Type of cooling* | *Time for cooling to 500° F, hr* |
|---|---|---|---|
| 1950 | 17 | Air | 1 |
| 1925 | 23 | Furnace at reduced power | 7 |
| 1975 | 24 | Furnace; power off | 4 |

Most of the coating spalled from the specimens which were air cooled with the retort removed from the furnace. Only a small amount of coating spalled from the samples which were furnace cooled. No differences were noted in specimens treated by the two furnace-cooling cycles.

### Testing and Evaluation

Evaluation of the coatings was based primarily on metallographic examination of sections cut from sprayed specimens. Some peel tests were made to determine the adhesion of the coating-uranium bond. No specimens suitable for corrosion tests were made, but these would provide the ultimate acceptance test for the coating procedure.

The structure of as-sprayed and heat-treated specimens are shown in Figs. 5 and 6, respectively. Examination of the bond areas was made on unetched specimens. The bond of the as-prayed coatings was good in some areas, but was not continuous. The unbonded areas may have resulted from the sectioning and polishing procedures, although the original cut sections were ground down about $\frac{1}{8}$ in. after mounting, to expose the surface for final polishing. Some uranium appears to have been melted by the spray and has solidified in the coating. A film on the uranium was apparent in other areas of the as-sprayed coatings. Some sections of the heat-treated specimens appeared to have excellent bonds. The film present on the uranium surfaces before spraying appears to have been absorbed during the heat treatment.

Examination of the structure of the coating was made on specimens which were etched. The laminar structure typical of sprayed metal was not observed throughout the coatings. Rounded particles of zirconium which did not deform on impact were contained in the coatings forming many voids. These particles ranged from 0.005 to 0.015 in. diam. Failure to obtain a

laminar structure was probably caused by one or more of the following factors: low velocity of the particles, low particle heat content, or large particle size. The zirconium appeared to be contaminated from impurities in the argon atmosphere.

Heat treatment after spraying was effective in eliminating the boundaries between individual spray particles. Diffusion of the zirconium and uranium occurred at the interface, with the rate of diffusion of the uranium apparently much higher than that of the zirconium. Two diffusion layers are apparent, as shown in Fig. 6: a thin bond-area phase, and a wide diffusion zone extending about 0.006 in. into the spray coating.

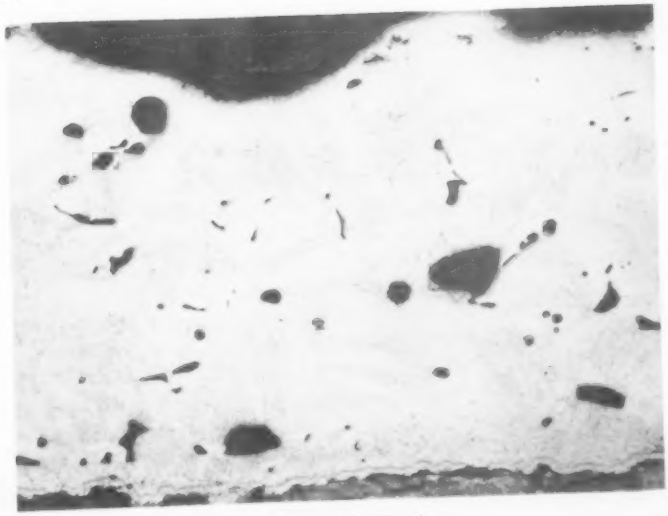
Peel tests of both as-sprayed and heat-treated specimens indicated good adhesion between the zirconium coating and the uranium.

## Recommendations

A workable system for metal spraying in inert atmospheres has been developed, and additional work with this equipment should bring considerable improvement. A better knowledge of the effects of variables in the operation of the arc-spray equipment will give a basic foundation for study of any particular coating problem. The major variables which are not completely understood at present are the influence of the forces within the arc itself. Since no comparable arc system has been studied, it is difficult to draw analogies from the available information on arc characteristics. Once this spray system is more fully understood, it will provide a valuable tool for depositing metal coatings which cannot now be applied by the metal-spray process.

Although the zirconium coatings which have been produced did not appear to offer the necessary corrosion protection for uranium, further study should result in improvements in these coatings. The following factors which affect zirconium coatings on uranium in particular should be studied more thoroughly: (1) surface condition of the uranium before spraying; (2) preheat of the uranium before spraying; (3) movement of the uranium relative to the arc; (4) operating conditions of the arc-spray equipment necessary to produce finer sprays when using zirconium in argon or helium atmospheres; and (5) consolidation of the coatings before heat treatment by rolling, peening or pressing.

X 250 As polished




X 75 $CH_2O$, $HNO_3$, HF etch

Fig. 6 Zirconium coating on uranium, heat-treated 24 hr at 1950° F

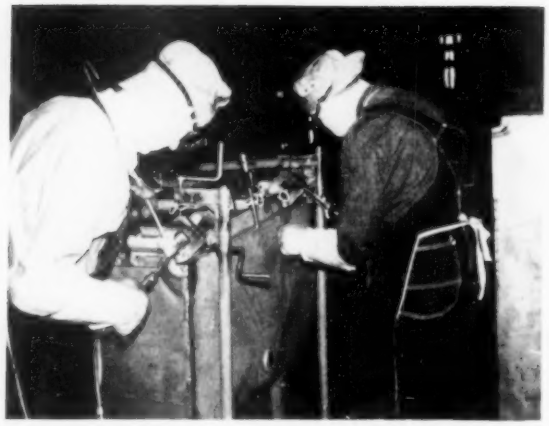


Fig. 1 Corner welding of 20-gage enameling iron with the parts clamped on water-cooled blocks

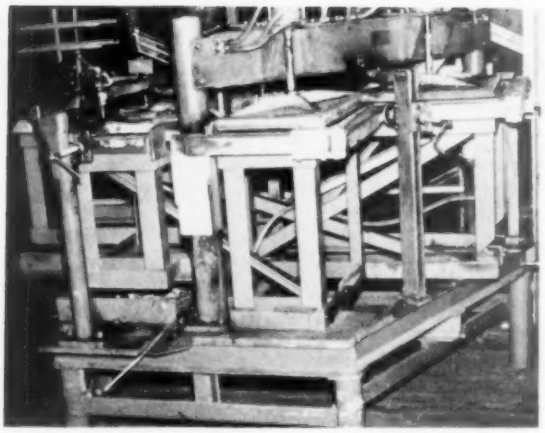


Fig. 2 Water-cooled fixture for an odd-shaped part

# USES OF OXYGEN AND ACETYLENE GASES IN THE REFRIGERATOR INDUSTRY

*Many production uses, from welding sheet metal to brazing and even leak detection, are described by the author*

BY PAUL BOWMAN

The oxyacetylene flame has always been one of the "tools" used in the refrigerator industry. In the St. Paul Division of Whirlpool Corporation, the oxyacetylene torch has many production uses from welding sheet metal to silver brazing and even leak detection. In fact, the uses are so great that acetylene and oxygen gases are piped throughout the plant with approximately 3000 ft of piping for each from a central source. In our plant, the numerous uses permit us to generate economically our own acetylene and thus the low cost opens other uses for it.

## Welding

Eighteen and 20 gage sheets, both cold-rolled steel and enameling iron, are welded (see Figs. 1 and 2). The majority of it is on enameling iron which is a very low carbon, special sheet used for parts to be porcelain enameled. The cold-rolled steel is SAE 1010 and has slightly better weldability than the enameling iron.

On low-production items, it is more economical to notch and form on simple dies and then gas weld on low-cost holding fixtures than it is to buy expensive dies and draw the part or even to weld it automatically. Porcelained liners, interior rails, drip pans and interior doors for ice cube machines and for large commercial refrigerators are low-production items (less than 300 week) that we make (see Figs. 3 and 4).

Liners are corner welded by clamping to water-cooled steel backings with a $\frac{1}{4}$- by $\frac{1}{4}$-in. groove behind the joint. Two corner designs are used; one is a simple 90° corner weld while the other is a 45° corner which is used to provide a slightly-rounded inside corner.

Other parts such as a drain pan or a door have the corners welded without backing. A simple fixture holds over-all dimensions. When necessary, the fixture is mounted on a pivot on a floor stand to provide downhand welding conditions.

The torches are used with a #2 tip (#64 drill) and a neutral flame. The parts are hand hammered when necessary to fit tight. A filler rod of $\frac{1}{16}$-in. sheared strips of the same material is used as necessary.

Porcelain enamel problems over a gas-welded joint are much greater than those of an electrical seam weld. Boiling of the porcelain in the weld area during firing at 1500° F causes rejects. These defects are caused by impurities in the weld. An oxidizing flame causes the most trouble. Excessive penetration also is trouble-

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Paper presented at the 1957 Annual Convention, International Acetylene Association, Minneapolis, Minn., April 1-3, 1957.

Fig. 3 Welding notched corners

Fig. 4 Free-hand welding of notched corners

Fig. 5 Reinforcing a corner with brass

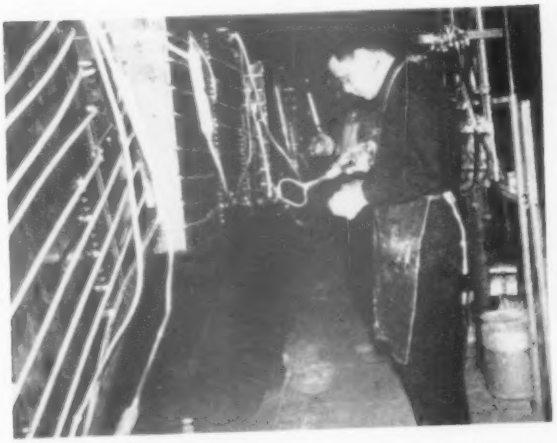

Fig. 6 Silver brazing copper tubing to copper tubing

some. Most work is welded from the outside or the back side for easy welding and is porcelained on the inside (a refrigerator liner for example). A good welder will weld about 8 ipm with a neutral flame and have slightly less than 100% penetration. This weld gives very little trouble in porcelain, but not all production line welders are that good.

In cases where there is heavy weld scale on the side to be finished, it is removed by grinding. We have also used a portable sand blaster with good success and at a low cost.

### *Braze Welding*

Braze welding cold-rolled sheets is widely used in refrigerator construction to close a corner or to fill and reinforce a notched corner on parts to be painted (see Fig. 5). Brazing with a $\frac{1}{8}$-in. diam low-fuming bronze rod and a compounded borax-type flux with a #2 tip does not warp the parts and it is easily metal finished to give a smooth, continuous surface that does not show after painting. Often a gas-type flux is used in place of the borax.

### *Silver Brazing*

The refrigeration system is composed of various amounts and combinations of copper, aluminum, stainless steel and steel tubing connected in a closed circuit to a compressor. All joints except those to aluminum are silver brazed. The joints are made by expanding one tube and inserting the other one $\frac{3}{4}$ in. The clearance is 0.002 to 0.005 in. Dry nitrogen gas is introduced inside the tubing to prevent formation of scale and keep the inside clean.

1. Copper-to-copper joints are the easiest to braze (Figs. 6 to 9). After the tubes are inserted into one another, a small amount of a standard proprietary flux cut with $\frac{2}{3}$ water is carefully brushed around the joint. The flux is kept in small plastic containers. The joint is heated with a dual tube, multiflame torch which has 5 #68 drill size holes in each tip. Five pounds oxygen pressure and ten pounds acetylene pressure are used with a neutral flame. When the flux melts, a 35% silver alloy is fed into the joint. Where the position of the joint permits, we use pre-applied rings of the

Fig. 7 Sealing off crimped tubing (under pressure) with silver braze

Fig. 9 Making a "T" joint on $\frac{7}{8}$-in. copper tubing

Fig. 8 Making a "T" joint with formed tube parts and silver braze

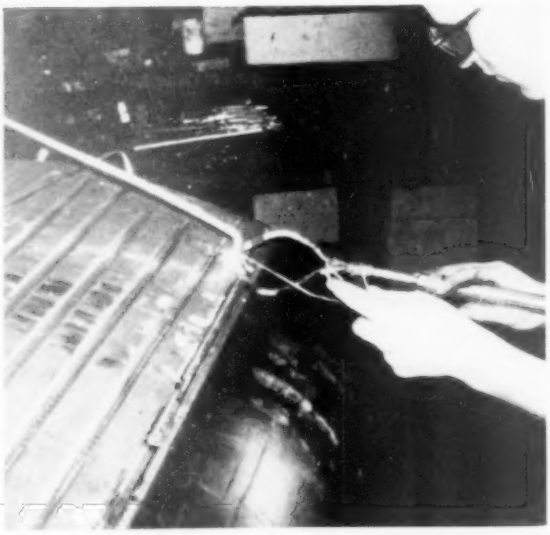

Fig. 10 Silver brazing copper tubing to stainless steel

same material. A low-silver alloy with about 5% phosphorus could be used on copper-to-copper joints. Our Engineering Department has not yet permitted its use on steel due to possible brittle joints, and since most of the joints made are copper-to-steel or steel-to-steel, we use only one material to avoid mistakes by production.

2. Silver brazing of copper-to-steel tubing follows the procedure except the flux is cut with only $\frac{1}{3}$ water and the tubes are inserted half way, flux carefully applied and then the tubes pushed all the way together.

3. Much steel tubing is used and many of the joints are steel-to-steel. The procedure used is the same as for brazing copper to steel tubing.

4. In some connections, copper tubing is silver brazed to Type 302 stainless steel. (Fig. 10). Here again the procedure is the same except a 50% silver alloy with 3% nickel is used to avoid possible crevice corrosion and subsequent leaks. We also paint these joints with a rust-resisting compound.

Whenever possible, a subassembly is leak tested. We prefer 400-lb per sq in. dry air (−60° F dew point) in the tubing and immersion under water to find leaks. When this is not possible, we apply pressure and use a soap solution brushed or flowed over the joint. These are the most economical and the most positive methods.

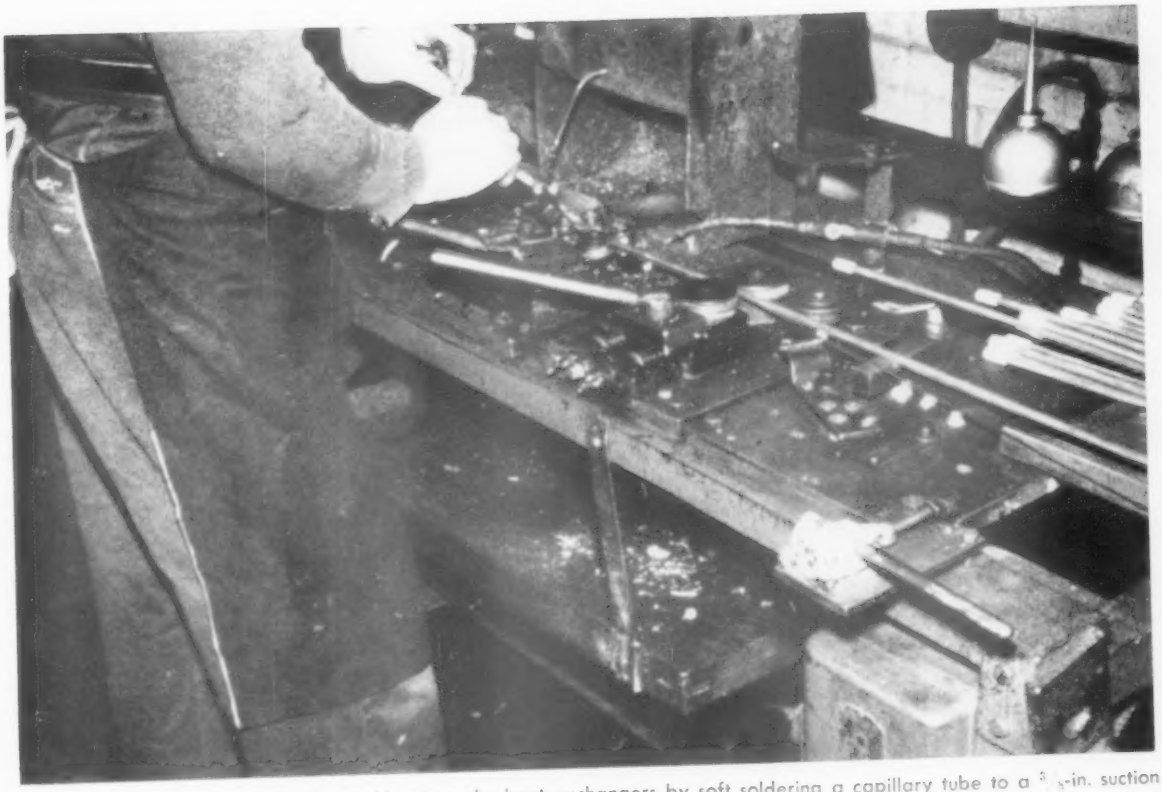

Fig. 11 A special semiautomatic machine to make heat exchangers by soft soldering a capillary tube to a $\frac{3}{8}$-in. suction tube using an acetylene torch mounted in the machine

After a refrigeration system is completed and charged with freon, a very sensitive halide leak detector is used to double check for leaks.

There are an average of 17 joints made on a system, and the leakers in our plant are 0.002%.

### Soldering

Nearly all soldering is done with gases other than acetylene; however, we have two special heat-exchanger soldering machines that use an acetylene multiflame heating torch with 5 #68 drill holes in the tip (Fig. 11). An 0.081-in. OD copper capillary tube is soldered to a straight length of $\frac{3}{8}$-in. OD copper suction tube for about 5 ft. The two pieces are gripped between motor-driven drive rolls that move them over the acetylene torch at a speed of 12 fpm. The torch is automatically lit from a pilot at the same time the motor starts to move the tubing. This is controlled by the operator with a foot switch. An 0.62-in. diam 40-60 acid core solder is fed to the joint between the tubes 3 in. behind the torch. The tubes pass through a second set of pinch rolls and a small stream of water flows over the tubes as they come out.

These machines have been in use for over 6 yr with excellent success. The acetylene torch was selected for heating because for us it was only a small fraction of the cost of any other method. Our bulk usage of gases gives a good operating cost and maintenance is nil.

### Freon Leak Testing

Halide leak-detector torches (Fig. 12) are used for preliminary leak checks on refrigeration systems charged with freon refrigerant. These are hand torches that have a thin $\frac{1}{2}$-in. diam copper sheet in an acetylene-air flame. The torch asperates its air through a 12-in. length of rubber hose. This hose is held up to the suspected leak area, and if any freon is drawn in with the air, the red-hot copper reacts with it and changes the color of the normally light blue flame to green. One such use in our plant is to check the sealed off charging tube immediately after sealing so the operator can be sure before the cabinet leaves this station.

Fig. 12 An acetylene-air flame halide-detection torch

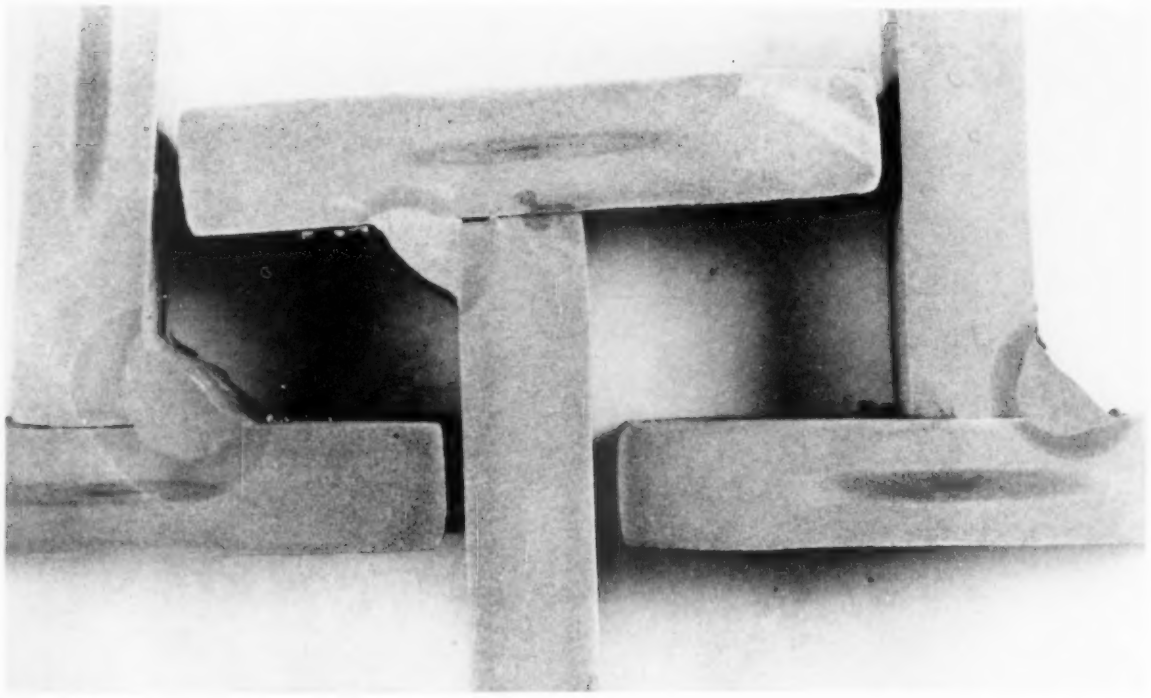

Fig. 1 Good fit-up—excellent welds. X 4

# REVISED WELDING PRACTICES PAY OFF IN THE JET-ENGINE INDUSTRY

*Proper fit of parts described as consistently leading to quality welds, provided that the other factors such as adequate machine capacity, cleanliness of parts, etc., are taken care of*

BY F. J. BACON

## The Role of Welding in Jet-Engine Manufacturing

It has been determined that operations directly associated with welding account for over one-fourth of the total labor dollars in the manufacture of jet engines at the Aircraft Gas Turbine Division, Cincinnati, Ohio. Because of its nature, welding also has been a source of major problems. Variables such as distortion, shrinkage, stresses, actual weld size, etc. are inherent in welding. *A "hard-headed" analysis of the whole problem area indicated that positive control of the fit of parts to be welded could bring nearly all of the other variables under control* (Fig. 1).

The subject of fit of parts to be welded has been discussed, debated, argued, maligned, misunderstood, misinterpreted, used to advantage, proven, disapproved, misused and generally tossed around as much or more than any other element common to welded fabrication practices. It is our conviction that its importance cannot be over-emphasized. This emphasis on fit of parts is particularly important in the jet-engine industry as a whole where tolerances that once were adequate for machined surfaces often must be

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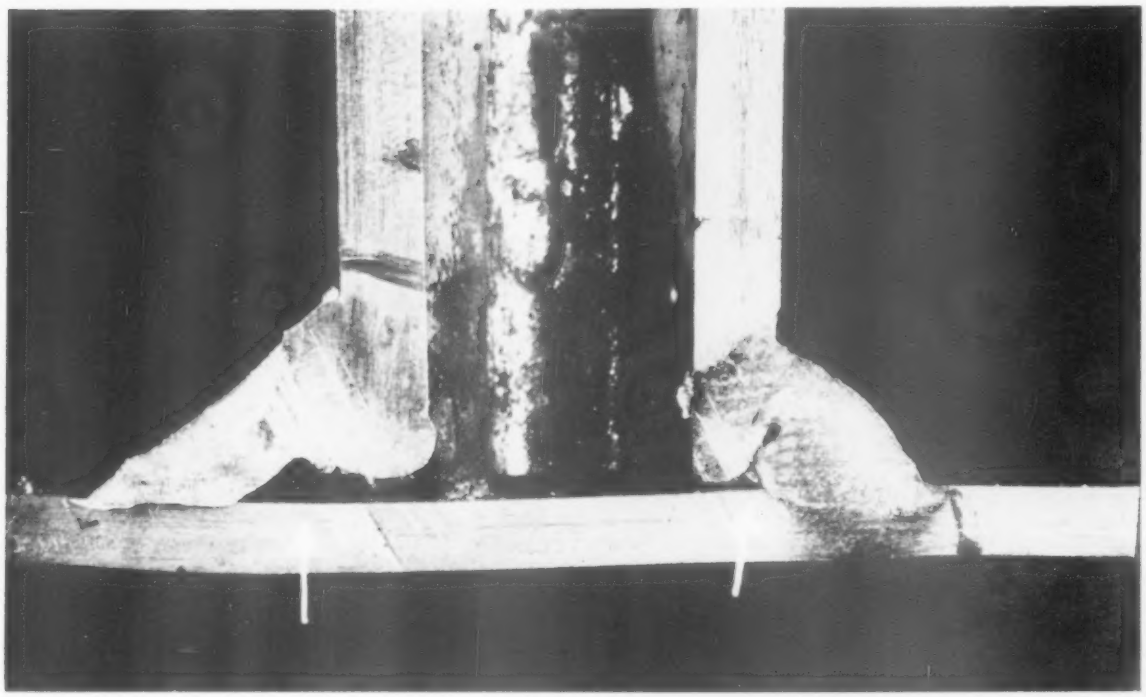

Fig. 2 Fillet weld, strut end to outer casing: (1) welds app. 400% oversize; (2) lack of penetration; (3) slag inclusions; (4) severe warping of sheet-metal skin; (5) undercut. X 4

maintained on rough weldments.

## Some Fit-up Standards That Are Being Used

Standards for fit of parts to be *resistance welded* have been established for some time. The necessity for such standards became evident quite early. This was the result of the fact that with fits made to a certain standard, quality welds could be consistently made, providing the other factors such as adequate machine capacity, cleanliness of parts, etc., were taken care of. Failure to adhere to the fit standard provided only scrap.

Despite this established fact, attempts were sometimes made to produce quality resistance welds on production units with components well outside the limits established. These attempts have always resulted in indecision, rework, rejects, extra costs and delayed schedules.

## The Basic Cause and Results of Loose Fits for Arc Welding

It has been common knowledge to planning men, welders, supervisors and others that a sizable gap could be bridged when using the metal-arc process. A skillful operator can quite easily bridge an opening 0.090 in., and the surface appearance of the weld will or can be equal to that made with a metal-to-metal fit. This is more apt to be true on fillet welds than elsewhere.

If surface appearance were the only requirement, all would be well. Even surface appearance and apparent weld size could be acceptable. Unfortunately, the case is quite different. The cooling and shrinking weld deposit will exert an almost irresistible force, most of it aimed at progressively closing any gap. When successful, as it often is, severe buckling, shrinking, warping, etc., is the usual end result. Cracks either visible or in the root of the weld are to be expected, as a matter of course (Fig. 2).

It is obvious that random, localized, extremely-high stressed areas with their well-known dangers will be present in all such cases.

The introduction and wide acceptance of the inert-arc processes for welding makes the fit of parts even more critical.

On gages of 0.062 and under, the surface tension of the molten metal is barely enough to support it when making flush square-groove butt welds. Obviously, even a small gap will simply cause this metal to drop through. Additional filler metal will allow the part to be welded at additional costs, poorer quality, increased shrinkage, etc.

Many components consist of sheet metal cylinders or cones with flanges butt welded to each end. Any radial mismatch between the so-called welding lip on the flange and the sheet metal section, will obviously reduce the cross section to be welded. For example, on 0.030-in. thickness material a 0.015-in. mismatch at any area means that at that area the welder or machine is required to weld the equivalent of approximately 0.015-in. material. A good manual operator can adjust

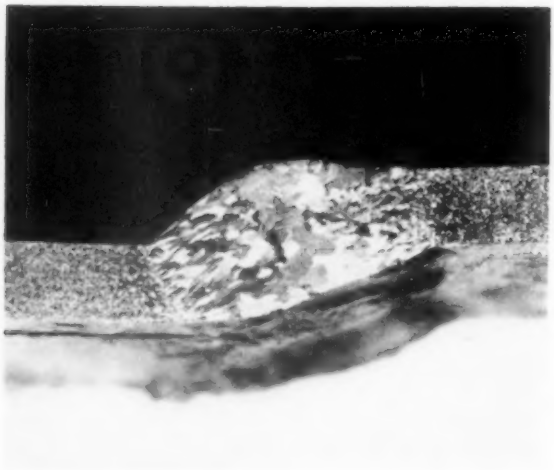

Fig. 3 Butt weld in mismatched 0.062-in. thick sheet metal: (1) low tensile value; (2) a natural stress raiser; (3) severe notch effect at top of lower sheet and weld; (4) weld deposit approx. 300% oversize; (5) can only be made manually. X 7

to this error, *and providing the off-set condition of the finished product is acceptable*, he *can* do the job. An automatic welding setup with this type of error will naturally and unavoidably produce rework or scrap.

## New Requirements

In the jet-engine fabrication programs, many new super alloys are constantly being introduced. They are usually "fearful and wonderful" to contemplate from a welding standpoint. They may be hotshot, cold worked, have a low melting phase, require preheat, postheat, heavy restraint, no restraint, etc., etc., whether singly or in any combination. Many of them can only be consistently welded under ideal conditions.

In combination with the improvement in available materials from an engineering point of view, there is a constant demand for more accuracy, less material in flanges, etc. and *smoother sheet-metal contours*. This demand is accompanied by an increase in the number of small intricate webbs, stiffeners, braces, flanged openings and close-tolerance complex contours.

Any *mismatch of parts to be butt welded will result in an offset condition;* The resultant joggle is a natural stress raiser, reduces the effective cross section from a strength factor, and on notch sensitive materials is almost useless (Fig. 3).

Any attempt to flirt with *fits* of *parts* much less than perfect, is to court grief and disaster at the same time. The reasons should be apparent:

## Negative Results of Poor Fit-up

Poor or inadequate fit of parts to be welded always has and will continue to give the following results: (1) lower quality welds, (2) increased distortion, (3) uncontrollable variables in shrinkage factors, (4) increased welding costs, (5) higher incident of rework and scrap, and (6) making fully-automatic quality welding practically an impossibility.

To elaborate further on the absolute necessity of establishing standards of weld preparations, fit of component parts, and *adhering to them*, if any semblance of distortion and/or shrinkage limits are required, is to belabor the obvious. This need is not confined to any one area or company but is general throughout the industry.

We feel confident that the well-known exceptions to fit-up requirements will be used again in attempts to refute many of our claims. Of course, *accurately* predetermined openings are often used in welding for obvious reasons, whenever such is the case, the accuracy of fit, and gap, is even more critical.

## Suggested New Standards and How to Obtain Them

What is a good or excellent fit for arc welding purposes? Metal-to-metal contact throughout the entire joint in one plane, combined with a maximum mismatch of 20% of the material thickness in the opposite plane where it applies, would be considered adequate in most cases.

What is required to obtain fits to this standard?

May we suggest a few.

A. Sizing of many sheet-metal components.

B. Possibly a modest amount of selective fitting.

C. Consideration of *assembly* tools and processes to permit parts made to close tolerances to be easily assembled.

D. "In-process" machining or other means of precision trimming of some components and/or subassemblies prior to subsequent welding operations.

E. Some selective stock gage requirements may be required on occasion.

Will the benefits derived from such a program justify the *alleged* additional costs?

## Results Obtainable

Management was convinced that a comprehensive plan based on the premise of excellent fit of parts should be mandatory instead of debatable. This has produced the following results:

1. Vastly improved quality of welds in general with reduced rework and rejects.

2. Control over distortion and shrinkage factors to a degree thought impossible prior to this plan.

3. Recognition by design and procurement sections as a *superior* quality division in sheet-metal fabrication with the resultant preferential position for placing work.

4. The ability to use several new alloys early in production where excellent fit of parts was absolutely mandatory if welding was to be used as a process.

5. Permitting a long-range high-production program to be planned for automation in welding with full assurance of success, by elimination of the many variables caused by uncontrolled fit of parts.

In summary, we obtained improved quality, recognition where it counts, more business, better future planning, and naturally lower costs.

# ONE-THIRD BILLION DOLLAR BRAZING JOB

BY H. O. QUARTZ

This was no ordinary jeweler's job of brazing—this was far more silver than had ever before been brazed anytime in history. When Allis-Chalmers contracted to build magnets for the first magnetic separator of uranium isotopes for the original atom bombs, it was realized that a unique method of brazing was required to handle the 25,750,000 lb of silver that were to be used in the coil windings. Because of the war-time shortage of copper, silver from the United States mint had to be used in the magnetic coils of the Calutron.

Although built in 1943, details of the construction of the Calutron, as this machine was called, had been classified until recently.

Strong, carefully brazed joints in the coils were absolutely essential because the silver strip, in moving at a speed of 5 to 6 ipm after unwinding and passing tables, was then subject to tension as high as 21,500 psi at the tension stand, the straightening rolls and the winding tables (Figs. 1 and 2).

The silver arrived at A-C's West Allis, Wis. works in coils containing strips $^{3}/_{16}$ in. thick, 3 in. wide, and weighing 350 lb. Wrapped individually in paper, the coils resembled automobile tires wrapped for shipment.

The strips were saw-cut at 45 deg to make the joint stronger, using turpentine as a cutting lubricant. Following this, they were washed with carbon tetrachloride. Almost every conceivable combination of silver solders and fluxes was tried. After extensive tensile and strength tests, a BCuP-5 filler metal which requires no flux, was used to solder the joints. A ribbon of pre-cut BCuP-5 filler metal 0.005 in. thick and with length and width equal to the cross section of the joint face, left a deposit of filler metal 0.002 to 0.003 in. thick between the joint surfaces after brazing. This was just enough to provide a strong joint. A pressure of 40 psi was maintained on the joint during brazing by an air clamp pushing the strips together length-wise.

A special oxyacetylene torch which gave uniform heating also had to be developed. It was mounted on the brazing table so that the tip was $1^{1}/_{2}$ in. from the strip. The special tip was water cooled; it had ten jets of flame that straddled the joint $1^{3}/_{4}$ in. on either side so that the cones of flame never came in contact with the solder.

The joint required less than a minute to clean by hand with a fine emery wheel and when tested for tension and porosity, all the test joints withstood more than the 21,500 psi and showed little porosity. In fact, the brazing was generally so well done that the joints had to be painted so that the inspectors could readily find the point of junction.

One of the interesting points noted was that only a small amount of silver was lost in the manufacture of these magnet coils in spite of the large tonnage. When the ends of the strip were cut off by the saw, the silver dust would accumulate on the floor; this was picked up regularly by a vacuum cleaner and placed in a "scrap" container along with the cut-off ends of the strips.

Many of the magnets are still in use today at Oak Ridge. One group is used in process development and production of stable isotopes. Others have been adapted for use in a cyclotron, for separation of plutonium isotopes, and for research and development in controlled thermonuclear experiments.

H. O. Quartz is Consultant associated with the Allis-Chalmers Mfg. Co., Milwaukee, Wis.

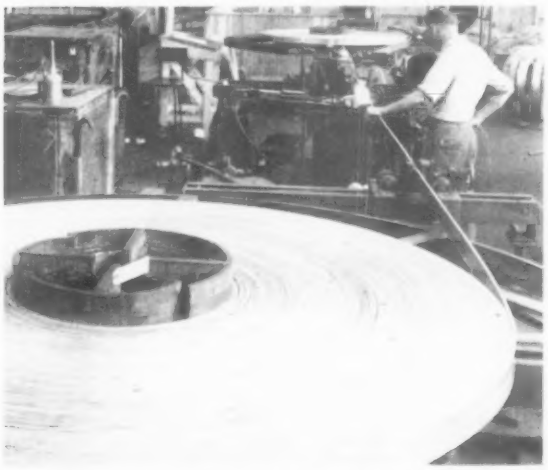

Fig. 1 Stationary cutting and brazing machine

Fig. 2 Winding machine

# FILLER METAL COMPARISON CHARTS .... AWS A5.0-57

*The information in these comparison charts has been obtained from the manufacturer or supplier of the particular filler metal at the time of issue.* THE AMERICAN WELDING SOCIETY *assumes no responsibility for the accuracy of the listings. Filler metals are not "approved" by* THE AMERICAN WELDING SOCIETY. *The manufacturer or supplier should be consulted regarding his guarantee of compliance to specifications.*

## Foreword

The AMERICAN WELDING SOCIETY receives many inquiries dealing with filler metals and their classifications. (Filler metals are classified by a joint committee of the AMERICAN WELDING SOCIETY and the American Society for Testing Materials.) The questions most often asked are:

(1) What classification is Brand X?

(2) Is Brand X the same classification as Brand Y?

(3) Who makes it and distributes it?

Although some manufacturers print charts showing this information, none of these charts are all-inclusive enough to answer adequately most inquiries. In many cases, it is necessary to consult a number of different manufacturers' catalogues before the answer is obtained. In other cases, the information is not available.

As a service to its members and all others who use welding, the SOCIETY decided to publish a comprehensive group of charts showing the AWS-ASTM classifications and the filler metals, by brand name, that are in these classifications. Letters were sent to all known filler metal firms requesting their aid in the preparation of these charts. These organizations were asked to indicate those filler metals (by brand name) manufactured or distributed by them. *Filler Metal Comparison Charts* is the result of the replies received.

Comments concerning these charts are invited from users of this publication. Organizations wishing to have their filler metals listed should prepare a tabulation of their brand names and the corresponding AWS-ASTM classifications. If uncertainty exists regarding correct AWS-ASTM classifications, a form showing all classifications can be obtained from the AWS. Correspondence relating to this publication should be addressed to Technical Secretary, AMERICAN WELDING SOCIETY, 33 West 39th St., New York 18, N. Y.

## Manufacturers' Names and Addresses

Air Reduction Sales Co., 150 East 42nd St., New York 17, N. Y.
Aladdin Rod & Flux Manufacturing Co., 1300 Burton St., S. E., Grand Rapids 7, Mich.
All-State Welding Alloys Co., Inc., 249–55 Ferris Ave., White Plains, N. Y.
Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Allied Weld-Craft, Inc., 401 West South St., Indianapolis 25, Ind.
Alloy Rods Co., York, Pa.
Aluminum Company of America, New Kensington, Pa.
Aluminum Wire Products Co., Inc., 9 Naubuc Ave., Glastonbury, Conn.
American Brass Co., Waterbury 20, Conn.
American Chain & Cable Co., Inc., Page Steel and Wire Div., Monessen, Pa.
American Platinum Works, 231 New Jersey R.R. Ave., Newark 5, N. J.
American Welding Alloys Corp., 124 57th St., Brooklyn 20, N. Y.
Ampco Metal, Inc., 1745 S. Thirty-eighth St., Milwaukee 46, Wis.
Arcos Corp., 1500 South 50th St., Philadelphia 43, Pa.
Auto Arc-Weld Manufacturing Co., 9615 Meech Ave., Cleveland 5, Ohio
Belmont Smelting & Refining Works, 330 Belmont Ave., Brooklyn 7, N. Y.
Bridgeport Brass Co., Housatonic Ave. Plant, Bridgeport 2, Conn.
Canadian Liquid Air Co., Ltd., 1111 Beaver Hall Hill, Montreal, P.Q.
Champion Rivet Co., Harvard Ave. and East 108th St., Cleveland 5, Ohio
Cleveland Tungsten, Inc., 10200 Meech Ave., Cleveland 5, Ohio
Coast Metals, Inc., Little Ferry, N. J.
Collins-Edmonds, Inc., 4041 Ridge Ave., Bldg. No. 25, Philadelphia 29, Pa.
Crucible Steel Company of America, Oliver Bldg., Mellon Square, Pittsburgh 22, Pa.
Drawalloy Corp., Lincoln Highway West at Alloy St., York, Pa.
Fusion Engineering, 17921 Roseland Ave., Cleveland, Ohio
General Electric Co., 863 South Albemarle St., York, Pa.
Goldsmith Bros. Smelting & Refining Co., 1300 West 59th St., Chicago 36, Ill.
Handy & Harman, 82 Fulton St., New York 38, N. Y.
Harnischfeger Corp., 4400 W. National Ave., Milwaukee 46, Wis.
Haynes Stellite Co., Kokomo, Ind.
Hobart Brothers, Hobart Square, Troy, Ohio
International Nickel Co., Inc., 67 Wall St., New York 5, N.Y.
Kaiser Aluminum & Chemical Corp., 1924 Broadway, Oakland 12, Calif.
Lincoln Electric Co., 22801 St. Clair Ave., Cleveland 17, Ohio
Linde Co., 30 East 42nd St., New York 17, N. Y.
Liquid Carbonic Corp., Industrial Gas Div., 3100 South Kedzie Ave., Chicago 23, Ill.
Marquette Manufacturing Co., Inc., 307 East Hennepin Ave., Minneapolis 14, Minn.
McKay Co., 1005 Liberty Ave., Pittsburgh 22, Pa.
Metal & Thermit Corp., Rahway, N. J.
Morgan Aluminum Welding Rod Co., Box 295, Mount Carmel, Pa.
Morris, Wheeler & Co. Inc., Fox St. and Roberts Ave., Philadelphia 29, Pa.
Mueller Brass Co., Port Huron, Mich.
National Cylinder Gas Co., 840 North Michigan Ave., Chicago 11, Ill.
North American Phillips Co., Lisbon Road, Lewiston, Me.
Pacific Welding Alloys Manufacturing Co., 310 North Ave. 21, Los Angeles 31, Calif.
Reid-Avery Co., Inc., Dundalk, Baltimore 22, Md.
Revere Copper and Brass, Inc., Rome, N. Y.
Reynolds Metals Co., 2500 South Third St., Louisville 1, Ky.
Shober Sales, Inc., 900 West Weber Ave., Stockton, Calif.
Sightmaster Corp., 111 Cedar St., New Rochelle, N. Y.
A. O. Smith Corp., 27th St. and Keefe Ave., Milwaukee 1, Wis.
Southern Oxygen Co., P. O. Box 5087, Washington 19, D. C.
Standard Steel & Wire Co., Bolivar, Pa.
Steel Company of Canada, Ltd., P. O. Box 160, Montreal, Canada
Sylvania Electric Products, Inc., Towanda, Pa.
Titan Metal Manufacturing Co., Bellefonte, Pa.
U. S. Electric Welder Corp., 1258 Door St., Toledo 7, Ohio
United Wire & Supply Corp., Providence 7, R.I.
Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich.
Westinghouse Electric Corp., 511 Wood St., P.O. Box 868, Pittsburgh 30, Pa.
Wooldridge Aluminum Welding Products, 1200 Eastern Ave., Malden, Mass.

# BRAZING *Filler Metal*

See *Tentative Specifications for Brazing Filler Metal* (AWS A5.8-52; ASTM B260-52)

| Manufacturers | AWS-ASTM Classification | BAlSi-1 | BAlSi-2 | BAlSi-3 | BAlSi-4 | BCuP-1 | BCuP-2 | BCuP-3 | BCuP-4 | BCuP-5 | BAg-1 | BAg-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Arcos 35 | – | – | Arcos 718 | – | – | Arcosil 5 | – | Arcosil 15 | Arcosil 45 | Arcosil 35 |
| Aladdin Rod & Flux Mfg. Co. | | – | – | – | Aladdin 718 | – | No. 21 | – | – | – | – | – |
| All-State Welding Alloys Co., Inc. | | – | – | – | – | – | – | – | – | – | – | – |
| Aluminum Co. of America | 4043 Brazing Rod | 713 Brazing Sheet | 718 Brazing Rod | 718 Brazing Rod Sheet | – | – | – | – | – | – | – | – |
| Aluminum Wire Products Co., Inc. | Alal 4043 | – | Alal 718 | Alal 718 | – | – | Silvaloy 5 | – | Silvaloy 15 | Silvaloy 45 | Silvaloy 35 |
| American Platinum Works | | – | – | – | – | – | – | – | – | – | – | – |
| Arcos Corp. | | – | – | Aumar 726 | Aumar 718 | Belmont BCuP-17 | Belmont BCuP-2 | – | – | – | – | – |
| Belmont Smelting & Refining Works | | – | – | – | – | – | Lo-Melt Copper | – | – | – | – | – |
| Canadian Liquid Air Co., Ltd. | LA 185 Aluminum | – | – | – | LA 353 Aluminum | – | – | Si-Fos 5 | – | Si-Fos 15 | Si-Bond 45 | Si-Bond 35 |
| Fusion Engineering | | – | – | – | – | – | – | – | GB No. 38 | GB No. 35 | GB No. 45 | GB No. 35 |
| Goldsmith Bros. Smelting & Refining Co. | | – | – | – | – | – | – | Sil-Fos 5 | – | Sil-Fos 15 | Easy-Flo 45 | Easy-Flo 35 |
| Handy & Harman | | – | – | – | – | – | – | – | – | No. 1800 | No. 1175 | – |
| Marquette Mfg. Co., Inc. | No. 7 | – | – | – | No. 718 Mar-Braz 718 | No. 1801 | – | – | – | – | – | – |
| Morris, Wheeler & Co. | | – | – | – | – | – | – | – | – | – | – | – |
| Reynolds Metals Co. | 4043 | – | – | – | – | – | Phoscop 0 Phos Copper | Phoscop 5 Phos Copper 5M | Phoscop 7 Phos Silver | Phoscop 15 Phos Silver 15 | Sil Bond 45 Cu Silver 45C | Sil Bond 35 Cu Silver 35C |
| United Wire & Supply Corp. | | – | – | – | – | Wire Deposit Strip | | | | | | |
| Westinghouse Elec. Corp. | | – | – | – | – | | | | | | | |

| Manufacturers | AWS-ASTM Classification | BAg-3 | BAg-4 | BAg-5 | BAg-6 | BAg-7 | BAg-8 | BAg-9 | BAg-10 | BAg-11 | BCuAu-1 | BCuAu-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Arcosil 1 | Arcosil 6 | Arcosil 5 | Arcosil 11 | Arcosil 17 | Arcosil 91 | Arcosil Easy | Arcosil Medium | Arcosil Hard | – | – |
| American Platinum Works | | Silvaloy 503 | Silvaloy 250 | Silvaloy A-25 | Silvaloy 350 | Silvaloy 300 | Silvaloy Easy | Silvaloy Medium | Silvaloy Hard | BCuAu-1 | BCuAu-2 | |
| Fusion Engineering | | 54-1200 | 54-1240 | – | – | – | – | – | – | – | – | – |
| Goldsmith Bros. Smelting & Refining Co. | | GB No. 350 | GB No. 240 | GB No. 145 | GB No. 250 | GB No. 56 | GB No. 72 | GB No. 65 | GB No. 70 | GB No. 75 | – | – |
| Handy & Harman | | Easy-Flo No. 3 | "50" | "45" | "Sil 50" | "Sil 56" | "Sil 72" | "Easy" | "Medium" | "Hard" | 9K Red Gold | 19.2K Red Gold |
| United Wire & Supply Corp. | | Sil Bond 50N | Sil 40N | Sil 45 | Sil 50 | Sil 56T | Sil 72 | Sil 65 | Sil 70 | Sil 75 | – | – |
| Westinghouse Elec. Corp. | | Co Silver 50N | Co Silver 40N | Co Silver 45 | Co Silver 50 | Co Silver 56T | Co Silver 72-2B | Co Silver 65 | Co Silver 70 | – | – | – |

| Manufacturers | AWS-ASTM Classification | BCu | BCuZn-1 | BCuZn-2 | BCuZn-3 | BCuZn-4 | BCuZn-5 | BCuZn-6 | BCuZn-7 | BMg | BNiCr | BAgMn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | – | – | Arcos 20 | Arcos 22 | – | – | – | – | – | – | Arcosil P |
| All-State Welding Alloys Co., Inc. | | – | – | – | Low Fuming Bronze | – | – | All-State No. 11 | – | All-State No. 61 | – | – |
| American Brass Co. | | Electrolytic Tough Pitch Cu 100 | Muntz Metal 60 | Tobin Bronze 465 | Anaconda 997 (Low Fuming) Bronze | – | – | Nickel Silver 678 | – | – | – | Silvaloy 850 |
| American Platinum Works | | – | – | – | – | – | – | – | – | – | – | – |
| Ampco Metal, Inc. | | – | – | – | Ampco-Braz No. 3 | – | – | Ampco-Braz No. 1 | – | – | – | – |
| Belmont Smelting & Refining Works | | Belmont BCu | – | – | – | Belmont Hotbite BCuZn-4 | Belmont Hotbite BCuZn-5 | – | Belmont BCuZn-7 | – | – | – |
| Bridgeport Brass Co. | | – | – | Bronze 196 | Manganese 192 | – | – | Nickel Silver 546 | – | – | – | – |
| Canadian Liquid Air Co., Ltd. | | – | – | – | Aiten Super Bronze, "FL" Bronze | – | – | – | – | – | No. 56 | – |
| Coast Metals, Inc. | | – | – | – | – | – | – | – | – | – | – | GB No. 85 |
| Goldsmith Bros. Smelting & Refining Co. | | – | – | – | – | – | – | – | – | – | – | 85Ag-15Mn |
| Handy & Harman | | – | – | – | – | – | – | – | – | – | – | – |
| Marquette Mfg. Co., Inc. | | – | – | No. 20 | No. 30, 32F.C. | – | – | No. 39, 38F.C. | – | – | – | – |
| National Cylinder Gas Co. | | – | – | NCu No. 3000 | NCu No. 3500, 3101 | – | – | NCu 5200 | – | NCu No. 401 | – | – |
| Revere Copper & Brass, Inc. | | Phosphor Deoxidized | Brass 181 | Bronze 380 | 456 (Low Fuming) | – | – | – | – | – | – | – |
| Southern Oxygen Co. | | BCu | BCuZn-1 | BCuZn-2 | BCuZn-3 | BCuZn-4 | BCuZn-5 | BCuZn-6 | BCuZn-7 | – | – | – |
| Titan Metal Mfg. Co. | | – | Penn Bronze No. 16 | Naval Bronze No. 60 | Manganese Bronze No. 17 | – | – | – | – | – | – | Sil 85M |
| United Wire & Supply Corp. | | – | – | – | – | – | – | – | – | – | Nicrobraz (Std) | – |
| Wall Colmonoy Corp. | | – | – | – | – | – | – | – | – | – | – | Co Silver 15 |
| Westinghouse Elec. Corp. | | – | – | – | – | – | – | – | – | – | – | – |

# Covered STAINLESS STEEL *Electrodes*

*See Tentative Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes (AWS A5.4-55; ASTM A298-55T)*

| Manufacturers | AWS-ASTM Classification | E308-15 | E308-16 | E308ELC-15 | E308ELC-16 | E309-15 | E309-16 | E309Cb-15 | E309Cb-16 | E309Mo-15 | E309Mo-16 | E310-15 | E310-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Airco 19-9 DC | Airco 19-9 AC-DC | – | Airco 19-9LC | Airco 25-12 DC | Airco 25-12 AC-DC | – | Airco 25-12 Cb AC-DC | – | – | Airco 25-20 DC | Airco 25-20 AC-DC |
| Allied Weld-Craft, Inc. | | Stain-Craft 308-Line | Stain-Craft 308 AC-DC | Stain-Craft 308ELC-Line | Stain-Craft 308ELC AC-DC | Stain-Craft 309-Line | Stain-Craft 309 AC-DC | Stain-Craft 309Cb-Line | Stain-Craft 309Cb AC-DC | Stain-Craft 309Mo-Line | Stain-Craft 309Mo AC-DC | Stain-Craft 310-Line | Stain-Craft 310 AC-DC |
| Alloy Rods Co. | | Accalloy 308 Line | Accalloy 308 AC-DC | Accalloy 308ELC Line | Accalloy 308ELC AC-DC | Accalloy 309 Line | Accalloy 309 AC-DC | Accalloy 309Cb-Line | Accalloy 309Cb AC-DC | Accalloy 309Mo-Line | Accalloy 309Mo AC-DC | Accalloy 310 Line | Accalloy 310 AC-DC |
| Arcos Corp. | | Arcoloy 308, Chromend K, Fabricor 308 | Stainend K | Chromend K-LC | – | Arcoloy 309, Chromend HC Fabricor 309 | Stainend HC | Chromend 25-12Cb | – | – | – | Arcoloy 310, Chromend HCN, Fabricor 310 | Stainend HCN |
| Champion Rivet Co. | | 308-1 | 308-2 | 308-1ELC | 308-2ELC | 309-1 | 309-2 | 309Cb-1 | 309Cb-2 | 309Mo-1 | 309Mo-2 | 310-1 | 310-2 |
| Crucible Steel Co. of America | | Rezistal 308-15 | Rezistal 308-16 | Rezistal 308LC-15 | Rezistal 308LC-16 | Rezistal 309-15 | Rezistal 309-16 | Rezistal 309Cb-15 | Rezistal 309Cb-16 | Rezistal 309Mo-15 | Rezistal 309Mo-16 | Rezistal 310-15 | Rezistal 310-16 |
| General Electric Co. | | W-1308 | W-2308 | W-1308LC | W-2308LC | W-1309 | W-2309 | W-1309Cb | W-2309Cb | W-1309Mo | W-2309Mo | W-1310 | W-2310 |
| Hornischfeger Corp. | | Harnstan 19-9 | Harnstan A 19-9 | Harnstan 19-9 ELC | Harnstan A 19-9 ELC | Harnstan 25-12 | Harnstan A 25-12 | Harnstan 25-12 Cb | Harnstan A 25-12 Cb | Harnstan 25-12 Mo | Harnstan A 25-12 Mo | Harnstan 25-20 | Harnstan A 25-20 |
| Hobart Brothers | | 308 DC | 308 AC | 308-ELC DC | 308-ELC AC | 309 DC | 309 AC | 309 Cb DC | 309 Cb AC | – | – | 310 DC | 310 AC |
| Lincoln Electric Co. | | Stainweld A6 | Stainweld A7 | – | – | – | – | Stainweld 6-Cb | – | – | – | Stainweld D6 | – |
| Marquette Mfg. Co., Inc. | | – | No. 308 | – | No. 308ELC | – | No. 309 | – | No. 309Cb | – | – | – | No. 310 |
| McKay Co. | | 19-9 DC Line, 19-9 DC Titania | 19-9 AC-DC | 19-9 ELC DC Line, 19-9 ELC DC Titania | 19-9 ELC AC-DC | 25-12 DC Line, 25-12 DC Titania | 25-12 AC-DC | 25-12Cb DC Line, 25-12Cb DC Titania | 25-12Cb AC-DC | 25-12Mo DC Line, 25-12Mo DC Titania | 25-12Mo AC-DC | 25-20 DC Line, 25-20 DC Titania | 25-20 AC-DC |
| Metal and Thermit Corp. | | Murex 19-9 (DC) | Murex 308 (AC-DC) | Murex 19-9ELC (DC) | Murex 308ELC (AC-DC) | Murex 25-12 (DC) | Murex 309 (AC-DC) | Murex 25-12Cb (DC) | Murex 309Cb (AC-DC) | – | – | Murex 25-20 (DC) | Murex 310 (AC-DC) |
| Morris, Wheeler & Co. | | Mor Weld 95 | Mor Weld 95 AC | Mor Weld 95ELC | Mor Weld 95ELC AC | Mor Weld 98 | Mor Weld 98 AC | Mor Weld 98 Cb | Mor Weld 98 Cb AC | Mor Weld 98 Mo | Mor Weld 98 Mo AC | Mor Weld 99 | Mor Weld 99 AC |
| National Cylinder Gas Co. | | Sunnweld E308-15 | Sunnweld E308-16 | Sunnweld E308ELC-15 | Sunnweld E308ELC-16 | Sunnweld E309-15 | Sunnweld E309-16 | Sunnweld E309Cb-15 | Sunnweld E309Cb-16 | Sunnweld E309Mo-15 | Sunnweld E309Mo-16 | Sunnweld E310-15 | Sunnweld E310-16 |
| Pacific Welding Alloys Mfg. Co. | | Stainalloy 308-15 | Stainalloy 308-16 | – | – | Stainalloy 309-15 | Stainalloy 309-16 | Stainalloy 309-Cb-15 | Stainalloy 309-Cb-16 | – | – | Stainalloy 310-15 | Stainalloy 310-16 |
| Reid-Avery Co. | | Racolloy 18-8 308 Line | Racolloy 18-8 308 Titania | Racolloy 18-8ELC 308ELC Line | Racolloy 18-8ELC 308ELC Titania | Racolloy 25-12 309 Line | Racolloy 25-12 309 Titania | Racolloy 25-12 309 Cb Line | Racolloy 25-12 309 Cb Titania | Racolloy 25-12 Mo 309 Mo Line | Racolloy 25-12 Mo 309 Mo Titania | Racolloy 25-20 310 Line | Racolloy 25-20 310 Titania |
| Shober Sales, Inc. | | Shober 308-15 | Shober 308-16 | – | Shober 308ELC | Shober 309-15 | Shober 309-16 | Shober 309Cb-15 | Shober 309Cb-16 | – | – | Shober 310-15 | Shober 310-16 |
| A. O. Smith Corp. | | SW-162 | SW-362 | SW-262 | – | SW-166 | – | SW-167 | – | – | – | SW-159 | SW-359 |
| Southern Oxygen Co. | | E308-15 | E308-16 | E308ELC-15 | E308ELC-16 | E309-15 | E309-16 | E309Cb-15 | E309Cb-16 | E309Mo-15 | E309Mo-16 | E310-15 | E310-16 |
| Westinghouse Electric Corp. | | 308-15 | 308-16 | 308ELC-15 | 308ELC-16 | 309-15 | 309-16 | 309Cb-15 | 309Cb-16 | – | – | 310-15 | 310-16 |

| Manufacturers | AWS-ASTM Classification | E310Cb-15 | E310Cb-16 | E310Mo-15 | E310Mo-16 | E312-15 | E312-16 | E316-15 | E316-16 | E316ELC-15 | E316ELC-16 | E317-15 | E317-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Airco 25-20 Cb DC | Airco 25-20 Cb AC-DC | – | Airco 25-20 Mo AC-DC | Airco 29-9 DC | Airco 29-9 AC-DC | Airco 19-12 Mo DC | Airco 19-12 Mo AC-DC | – | Airco 18-12Mo ELC AC-DC | – | Airco 18-12 1.5Mo AC-DC |
| Allied Weld-Craft, Inc. | | Stain-Craft 310Cb-Line | Stain-Craft 310Cb AC-DC | Stain-Craft 310Mo-Line | Stain-Craft 310Mo AC-DC | Stain-Craft 312-Line | Stain-Craft 312 AC-DC | Stain-Craft 316-Line | Stain-Craft 316 AC-DC | Stain-Craft 316ELC-Line | Stain-Craft 316ELC AC-DC | Stain-Craft 317-Line | Stain-Craft 317 AC-DC |
| Alloy Rods Co. | | Accalloy 310Cb Line | Accalloy 310Cb AC-DC | Accalloy 310Mo Line | Accalloy 310Mo AC-DC | Accalloy 312 Line | Accalloy 312 AC-DC | Accalloy 316 Line | Accalloy 316 AC-DC | Accalloy 316ELC Line | Accalloy 316ELC AC-DC | Accalloy 317 Line | Accalloy 317 AC-DC |
| Arcos Corp. | | Chromend 25-20 Cb | – | Chromend 25-20 Mo | – | Chromend 29-9 | Stainend 29-9 | Arcocor 316, Chromend KMn, Fabricor 316 | Stainend KMn | Chromend KMn-LC | – | Chromend 18-9Mo | – |
| Champion Rivet Co. | | 310Cb-1 | 310Cb-2 | 310Mo-1 | 310Mo-2 | 312-1 | 312-2 | 316-1 | 316-2 | 316-1ELC | 316-2ELC | 317-1 | 317-2 |
| Crucible Steel Co. of America | | Rezistal 310Cb-15 | Rezistal 310Cb-16 | Rezistal 310Mo-15 | Rezistal 310Mo-16 | Rezistal 312-15 | Rezistal 312-16 | Rezistal 316-15 | Rezistal 316-16 | Rezistal 316LC-15 | Rezistal 316LC-16 | Rezistal 317-15 | Rezistal 317-16 |
| General Electric Co. | | W-2310Cb | W-2310Cb | W-1310Mo | W-2310Mo | W-1312 | W-2312 | W-1316 | W-2316 | W-1316LC | W-2316LC | W-1317 | W-2317 |
| Hornischfeger Corp. | | Harnstan 25-20 Cb | Harnstan A 25-20 Cb | Harnstan 25-20 Mo | Harnstan A 25-20 Mo | Harnstan 29-9 | Harnstan A 29-9 | Harnstan 19-9 2Mo | Harnstan A 19-9 2Mo | Harnstan 19-9-2Mo ELC | Harnstan A 19-9-2Mo ELC | Harnstan 19-9-3Mo | Harnstan A 19-9-3Mo |
| Hobart Brothers | | 310Cb DC | 310Cb AC | 310Mo DC | 310Mo AC | 312 DC | 312 AC | 316 DC | 316 AC | 316ELC DC | 316ELC AC | 317 DC | 317 AC |
| Lincoln Electric Co. | | – | – | – | – | – | – | – | – | – | – | – | – |
| Marquette Mfg. Co., Inc. | | – | No. 310Cb | – | No. 310Mo | – | No. 312 | – | No. 316 | – | No. 316ELC | – | – |
| McKay Co. | | 25-20Cb DC Line, 25-20Cb DC Titania | 25-20Cb AC-DC | 25-20 Mo DC Line, 25-25 Mo DC Titania | 25-20 Mo AC-DC | 29-9 DC Line | 29-9 AC-DC | 19-9Mo (316) DC Line, 19-9Mo (316) DC Titania | 19-9Mo (316) AC-DC | 19-9Mo ELC (316ELC) DC Line, 19-9Mo ELC (316ELC) DC Titania | 19-9Mo ELC (316ELC) AC-DC | 19-9Mo (317) DC Line, 19-9Mo (317) DC Titania | 19-9Mo (317) AC-DC |
| Metal and Thermit Corp. | | Murex 25-20Cb (DC) | Murex 310Cb (AC-DC) | Murex 25-20Mo (DC) | Murex 310Mo (AC-DC) | Murex 29-9 (DC) | Murex 312 (AC-DC) | Murex 19-9Mo (DC) | Murex 316 (AC-DC) | Murex 19-9Mo ELC (DC) | Murex 316ELC (AC-DC) | Murex 19-9Mo (DC) | Murex 317 (AC-DC) |
| Morris, Wheeler & Co. | | Mor Weld 99Cb | Mor Weld 99Cb AC | Mor Weld 99Mo | Mor Weld 99Mo AC | Mor Weld 192 | Mor Weld 192 AC | Mor Weld 96 | Mor Weld 96 AC | Mor Weld 96ELC | Mor Weld 96ELC AC | Mor Weld 193 | Mor Weld 193 AC |
| National Cylinder Gas Co. | | Sunnweld E310Cb-15 | Sunnweld E310Cb-16 | Sunnweld E310Mo-15 | Sunnweld E310Mo-16 | Sunnweld E312-15 | Sunnweld E312-16 | Sunnweld E316-15 | Sunnweld E316-16 | Sunnweld E316ELC-15 | Sunnweld E316ELC-16 | Sunnweld E317-15 | Sunnweld E317-16 |
| Pacific Welding Alloys Mfg. Co. | | Stainalloy 310-Cb-15 | Stainalloy 310-Cb-16 | Stainalloy 310-Mo-15 | Stainalloy 310-Mo-16 | – | – | Stainalloy 316-15 | Stainalloy 316-16 | – | – | Stainalloy 317-15, 317-Cb-15 | Stainalloy 317-16, 317-Cb-16 |
| Reid-Avery Co. | | Racolloy 25-20Cb 310Cb Line | Racolloy 25-20Cb 310Cb Titania | Racolloy 25-20Mo 310Mo Line | Racolloy 25-20Mo 310Mo Titania | Racolloy 29-9 312 Line | Racolloy 29-9 312 Titania | Racolloy 18-12 316 Line | Racolloy 18-12 316 Titania | Racolloy 18-12ELC 316ELC Line | Racolloy 18-12ELC 316ELC Titania | Racolloy 18-12 317 Line | Racolloy 18-12 317 Titania |
| Shober Sales, Inc. | | Shober 310-Cb-15 | Shober 310Cb-16 | Shober 310Mo-15 | Shober 310Mo-16 | Shober 312-15 | Shober 312-16 | Shober 316-15 | Shober 316-16 | – | Shober 316ELC | Shober 317-15 | Shober 317-16 |
| A. O. Smith Corp. | | SW-169 | – | SW-368 | SW-368 | – | – | SW-160 | – | SW-260 | – | SW-161 | – |
| Southern Oxygen Co. | | E310Cb-15 | E310Cb-16 | E310Mo-15 | E310Mo-16 | E312-15 | E312-16 | E316-15 | E316-16 | E316ELC-15 | E316ELC-16 | E317-15 | E317-16 |
| Westinghouse Electric Corp. | | 310Cb-15 | 310Cb-16 | 310Mo-15 | 310Mo-16 | 312-15 | 312-16 | 316-15 | 316-16 | 316ELC-15 | 316ELC-16 | 317-15 | 317-16 |

## Covered STAINLESS STEEL *Electrodes* CONTINUED

| Manufacturers | AWS-ASTM Classification | E318-15 | E318-16 | E330-15 | E330-16 | E347-15 | E347-16 | E410-15 | E410-16 | E430-15 | E430-16 | E502-15 | E502-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | – | – | Airco 15Ni 15Cr DC | Airco 15Ni 15Cr AC-DC | Airco 19-9Cb DC | Airco 19-9Cb AC-DC | Airco 12Cr DC | – | Airco 16Cr DC | – | Airco 4-6 Cr Mo DC | – |
| Allied Weld-Craft, Inc. | | Stain-Craft 316-Lime | Stain-Craft 318 AC-DC | Stain-Craft 330-Lime | Stain-Craft 330 AC-DC | Stain-Craft 347-Lime | Stain-Craft 347 AC-DC | Stain-Craft 410-Lime | Stain-Craft 410 AC-DC | Stain-Craft 430-Lime | Stain-Craft 430 AC-DC | Stain-Craft 502-Lime | Stain-Craft 502 AC-DC |
| Alloy Rods Co. | | Arcaloy 318 Lime | Arcaloy 318 AC-DC | Arcaloy 330-Lime | Arcaloy 330 AC-DC | Arcaloy 347 Lime | Arcaloy 347 AC-DC | Arcaloy 410 Lime | Arcaloy 410 AC-DC | Arcaloy 430 Lime | Arcaloy 430 AC-DC | Arcaloy 502 Lime | Arcaloy 502 AC-DC |
| Arcos Corp. | | Chromend 4 Mo-Cb | – | Chromend 15-35 | – | Arcos 19 Mo, Chromend 19-9Cb, Fabricor 347 | Chromend 19-9Cb | Arcos 410, Chromend 12 | – | Chromend 16 | – | Chromend 6M | – |
| Champion Rivet Co. | | 316-1 | 316-2 | 330-1 | 330-2 | 347-1 | 347-2 | 410-1 | 410-2 | 430-1 | 430-2 | Champ 5A | 502-2 |
| Crucible Steel Co. of America | | Rezistal 318-15 | Rezistal 318-16 | Rezistal 330-15 | Rezistal 330-16 | Rezistal 347-15 | Rezistal 347-16 | Rezistal 410-15 | Rezistal 410-16 | Rezistal 430-15 | Rezistal 430-16 | Rezistal 502-15 | Rezistal 502-16 |
| General Electric Co. | | W-2318 | W-2318 | W-2330 | W-2330 | W-2347 | W-2347 | W-2410 | W-2410 | W-2430 | W-2430 | W-2502 | W-2502 |
| Harnischfeger Corp. | | – | – | – | – | Hardsteel A 18-8Cb | Hardsteel A 18-8Cb | Hardchrome 12 | – | Hardchrome 16 | – | – | Hardchrome 5 |
| Hobart Brothers | | – | – | 330 DC | 330 AC | 347 DC | 347 AC | 410 DC | 410 AC | 430 DC | 430 AC | 502 DC | – |
| Lincoln Electric Co. | | Stainweld C-Cb | – | – | – | Stainweld A8-Cb | Stainweld A8-Cb | – | – | – | – | – | – |
| Marquette Mfg. Co., Inc. | | – | No. 318 | – | No. 330 | – | No. 347 | – | No. 410 | – | No. 430 | – | No. 502 |
| McKay Co. | | 18-8Mo Cb DC Line, 18-8Mo Cb DC Titania | 18-8Mo Cb AC-DC | 15-35 DC Line, 15-35 DC Titania | 15-35 AC-DC | 18-8Cb DC Line, 18-8Cb DC Titania | 18-8Cb AC-DC | 12 Cr DC Line, 12 Cr DC Titania | 12 Cr AC-DC | 16 Cr DC Line, 16 Cr DC Titania | 16 Cr AC-DC | 5 Cr Mo DC Line, 5 Cr Mo DC Titania | 5 Cr Mo AC-DC |
| Metal and Thermit Corp. | | – | – | Mutex 15-35 (DC) | Mutex 330 (AC-DC) | Mutex 19-9Cb (DC) | Mutex 347 (AC-DC) | Mutex 12 Cr (DC) | Mutex 410 (AC-DC) | Mutex 16Cr (DC) | Mutex 430 (AC-DC) | Mutex Croloy 5A, Mutex 4-6 Chrome (DC) | Mutex 502 (AC-DC) |
| Morris, Wheeler & Co. | | Mor Weld 194 | Mor Weld 194 AC | Mor Weld 195 | Mor Weld 195 AC | Mor Weld 97 | Mor Weld 97 AC | Mor Weld 196 | Mor Weld 196 AC | Mor Weld 197 | Mor Weld 197 AC | Mor Weld 198 | Mor Weld 198 AC |
| National Cylinder Gas Co. | | Sunweld E318-15 | Sunweld E318-16 | Sunweld E330-15 | Sunweld E330-16 | Sunweld E347-15 | Sunweld E347-16 | Sunweld E410-15 | Sunweld E410-16 | Sunweld E430-15 | Sunweld E430-16 | Sunweld E502-15 | Sunweld E502-16 |
| Pacific Welding Alloys Mfg. Co. | | – | – | – | – | Stainalloy 347-15 | Stainalloy 347-16 | Stainalloy 410-15 | Stainalloy 410-16 | Stainalloy 430-15 | Stainalloy 430-16 | Stainalloy 502-15 | Stainalloy 502-16 |
| Reid-Avery Co. | | Raccoloy 18-8MoCb 318 Lime | Raccoloy 18-8MoCb 318 Titania | Raccoloy 15-35 330 Lime | Raccoloy 15-35 330 Titania | Raccoloy 18-8Cb 347 Lime | Raccoloy 18-8Cb 347 Titania | Raccoloy 12CrMo 410 Lime | Raccoloy 12CrMo 410 Titania | Raccoloy 430 430 Lime | Raccoloy 430 430 Titania | Raccoloy 5CrMo 502 Lime | Raccoloy 5CrMo 502 Titania |
| Shober Sales, Inc. | | Shober 318-15 | Shober 318-16 | Shober 330-15 | Shober 330-16 | Shober 347-15 | Shober 347-16 | Shober 410 | – | Shober 430 | – | Shober 502-15 | Shober 502-16 |
| A. O. Smith Corp. | | SW-158 | – | – | – | SW-157 | SW-257 | SW-253 | – | – | – | SW-151 | – |
| Southern Oxygen Co. | | E318-15 | E318-16 | E330-15 | E330-16 | E347-15 | E347-16 | E410-15 | E410-16 | E430-15 | E430-16 | E502-15 | E502-16 |
| Westinghouse Electric Corp. | | 318-15 | 318-16 | 330-15 | – | 347-15 | 347-16 | 410-15 | 410-16 | 430-15 | 430-16 | 502-15 | 502-16 |

## Bare STAINLESS STEEL *Welding Rods and Electrodes*

*See Tentative Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes (AWS A5.9-53, ASTM A371-53)*

| Manufacturers | AWS-ASTM Classification | ER 308 | ER 308L | ER 309 | ER 310 | ER 316 | ER 316L | ER 317 | ER 330 | ER 347 | ER 410 | ER 420 | ER 430 | ER 502 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Airco 308, Aircomatic A308 | Aircomatic A308 E L C | Airco 309, Aircomatic A309 | Airco 310, Aircomatic A310 | Airco 316, Aircomatic A316 | Aircomatic A316 E L C | – | – | Airco 347, Aircomatic A347 | – | – | – | – |
| Allegheny Ludlum Steel Corp. | | 308 | 308 L | 309 | 310 | 316 | 316 L | 317 | 330 | 347 | 410 | 420 | 430 | 502 |
| American Chain & Cable Co., Inc., Page Steel & Wire Div. | | Page A-S-308 | Page A-S-308L | Page A-S-309 | Page A-S-310 | Page A-S-316 | Page A-S-316L | – | – | Page A-S-347 | Page A-S-410 | Page A-S-420 | Page A-S-430 | Page A-S-502 |
| Arcos Corp. | | Chromend K | Chromend K L C | Chromend HC | Chromend HCN | Chromend KMo | Chromend KMoL C | – | Chromend 15-35 | Chromend 19-9Cb | Chromend 12 | Chromend 12C | Chromend 16 | Chromend 6M |
| Canadian Liquid Air Co., Ltd. | | Type 308 | Type 308 E L C | Type 309 | Type 310 | Type 316 | Type 316 E L C | – | – | Type 347 | Type 410 | – | Type 430 | Type 502 |
| Champion Rivet Co. | | 308 | 308 E L C | 309 | 310 | 316 | 316 E L C | 317 | 330 | 347 | 410 | 420 | 430 | 502 |
| Collins-Edmonds, Inc. | | C-E 308 | C-E 308 E L C | C-E 309 | C-E 310 | C-E 316 | C-E 316 E L C | C-E 317 | C-E 330 | C-E 347 | C-E 410 | C-E 420 | C-E 430 | C-E 502 |
| Crucible Steel Co. of America | | Rezistal 308 | Rezistal 308 L C | Rezistal 309 | Rezistal 310 | Rezistal 316 | Rezistal 316 L C | Rezistal 317 | Rezistal 330 | Rezistal 347 | Rezistal 410 | Rezistal 420 | Rezistal 430 | Rezistal 502 |
| Drawalloy Corp. | | Bare 308 | Bare 308 E L C | Bare 309 | Bare 310 | Bare 316 | Bare 316 E L C | – | Bare 330 | Bare 347 | Bare 410 | Bare 420 | Bare 430 | Bare 502 |
| General Electric Co. | | W-308 | W-308 L C | W-309 | W-310 | W-316 | W-316 L C | W-317 | W-330 | W-347 | W-410 | W-420 | W-430 | W-502 |
| Linde Air Products Co. | | – | Oxweld 308L, 61 | Oxweld 309 | Oxweld 310 | Oxweld 316, O-316 Cb-Ta | Oxweld 316L, O-316L | – | – | Oxweld 29, 60 | Oxweld O-410 | Oxweld 420 | Oxweld O-430 | Oxweld 502, O-502 |
| Marquette Mfg. Co., Inc. | | No. O-308 | – | – | – | – | – | – | – | – | – | – | – | – |
| McKay Co. | | 308 | 308 E L C | 309 | 310 | 316 | 316 E L C | 317 | 330 | 347 | 410 | 420 | 430 | 502 |
| Metal & Thermit Corp. | | Mutex 19-9 | Mutex 19-9 E L C | Mutex 25-12 | Mutex 25-20 | Mutex 19-9Mo | Mutex 19-9Mo E L C | – | Mutex 15-65 | Mutex 19-9Cb | Mutex 12CR | – | Mutex 16CR | Mutex 4-6CR |
| Morris, Wheeler & Co. | | Mor Weld 47 | – | – | – | Mor Weld 47A | – | – | – | Mor Weld 48 | – | – | – | – |
| National Cylinder Gas Co. | | NCG No. 301 | NCG No. 311 | NCG No. 323 | NCG No. 341 | – | – | – | – | NCG No. 351 | – | – | – | – |
| Reid-Avery Co. | | Raccoloy 308 | Raccoloy 308 E L C | Raccoloy 309 | Raccoloy 310 | Raccoloy 316 | Raccoloy 316 E L C | Raccoloy 317 | Raccoloy 330 | Raccoloy 347 | Raccoloy 410 | Raccoloy 420 | Raccoloy 430 | Raccoloy 502 |
| Southern Oxygen Co. | | ER 308 | – | – | ER 310 | ER 316 | – | – | – | ER 347 | – | – | – | – |

# HIGH TENSILE and LOW ALLOY STEEL *Electrodes*

*See Tentative Specifications for High Tensile and Low-Alloy Steel Covered Arc-Welding Electrodes (AWS A5.5-54; ASTM A316-54)*

| Manufacturers | AWS-ASTM Classification | E7010 | E7011 | E7015 | E7016 | E7020 | E8010 | E8011 | E8013 | E8015 | E8016 | E9010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Airco 83 [A1] | Airco 182 A1 | – | Airco 107 | Airco 94 [A1] | – | – | – | – | Airco 395, 396 [C1] | – |
| Alloy Rods Co. | | – | – | – | Atom Arc 7016, 7016M [A1] | – | – | – | – | – | Atom Arc 8016CM [B2], 8016N [C2] | – |
| Arcos Corp. | | – | – | – | Ductilend 70, Tensilend 70 | – | – | – | – | – | Tensilend 80, Chromend 1M [B2], Nickend 2 [C1], Nickend 3 [C2] | – |
| Canadian Liquid Air Co., Ltd. | | LA 7010 [A1] | – | – | – | – | – | – | – | – | – | – |
| Champion Rivet Co. | | Blue Streak 85 [A1] | – | Cloloy 3A [B2] | Hy-Lo, Speedemon 716, Speedemon 716-Mo [A1] | Black Devil 75 [A1] | – | – | – | – | – | – |
| General Electric Co. | | W-710A [A1] | W-711A [A1] | – | W-716B, Shieldex LH-1, Shieldex LH-2 | W-720A [A1] | – | – | – | – | W-816B, W-816A [C1] | – |
| Harnischfeger Corp. | | Cn 50 [A1] | Cn 50-1 [A1] | – | 70LA, 70LA2, P&H 75S, 70LB [B2] | Cn 50-2 [A1] | – | – | – | – | P&H 8, 80LF [B2], 80LF [B2], 75LF [C1] | – |
| Hobart Brothers | | No. 88 | – | – | No. 16, Rocket LH-16 | No. 111-HT | – | – | – | – | Rocket LH-R160 [B2], LH-616 [C2] | – |
| Lincoln Electric Co. | | Shieldarc 85, 85P | – | – | – | Jetweld 2HT | – | – | – | – | – | Shieldarc 90LH |
| Liquid Carbonic Corp. | | Liquid L-193 | Liquid L-82 | – | – | Liquid L-194 | – | – | – | – | Liquid L-84 | – |
| Marquette Mfg. Co., Inc. | | – | – | – | No. 7016 | – | – | No. 85 | – | – | – | – |
| McKay Co. | | – | – | – | Phurallov 70AC, 70AP | – | – | – | – | Phurallov 85 AC | 8016 | – |
| Metal & Thermit Corp. | | Mutex Mutex | Mutex MA | Mutex Cloloy [A1 B2] | Mutex Speedex LH, Speedex HTS, HTS-16, HTS-160 | Mutex DM | – | – | – | – | Mutex 8016 Q, HTS-80 | – |
| Morris, Wheeler & Co. | | Mor Weld 62 | Mor Weld 75 | Mor Weld 85 | Mor Weld 65AC | Mor Weld 61 | Mor Weld 765 | Mor Weld 764 | – | Mor Weld 65 | Mor Weld 80 AC, 86 B1 AC [B1] | Mor Weld 770 |
| National Cylinder Gas Co. | | Sunweld ML Y-50 [A1] | Sunweld ML Y-C [A1] | – | Sunweld 7016 | Sunweld ML Y-A [A1] | – | – | – | – | – | – |
| Pacific Welding Alloys Mfg. Co. | | Pacific E7010 | – | – | Pacific E7016 | – | – | – | – | – | – | – |
| Reid-Avery Co. | | Raco 74 [A1] | Raco 7011 [A1] | Raco 7015, 7015-A1 [A1] | Raco 7016, 7016-A1 [A1] | Raco 64 [A1] | Raco 8010 [B1] | Raco 8011 [B1] | Raco 8013 [B1] | Raco 8015, 8015 [B1,C1,C2] | Raco 8016, 8016 [B1,C1,C2] | Raco 9010 [B2] |
| Shaver Sales, Inc. | | 73 | – | – | 7016 | – | – | – | – | – | – | – |
| A.O. Smith Corp. | | SW-80, SW-75 [A1] | – | – | SW-64, SW-67 | SW-76 | – | – | – | – | SW-81, SW-79 [A1] | SW-95 |
| Southern Oxygen Co. | | E7010, E7010 [A1, B1, B2, B3] | E7011, E7011 [A1, B1, B2, B3] | E7015, E7015 [A1, B B2,B3,C1,C2] | E7016, E7016 [A1, B1 B2,B3,C1,C2] | E7020, E7020 [A1] | E8010, E8010 [A1, B1, B2, B3] | E8011, E8011 [A1, B1, B2, B3] | E8013, E8013 [B1, B2, B3] | E8015, E8015 [A1, B1, B2,B3,C1,C2] | E8016, E8016 [A1, B1, B2,B3,C1,C2] | E9010, E9010 [A1, B1, B2, B3] |
| Steel Co. of Canada, Ltd. | | Steico Electrod 710 [A1], 710P [A1] | Steico Electrod 711 [A1] | – | Steico Electrod 716D, 716 | Steico Electrod 720 [A1] | – | – | – | – | – | – |
| Westinghouse Electric Corp. | | XL-710, XL-710-A1 [A1] | ACP-711, ACP-711-A1 [A1] | – | Lon2-716 | DH-720, DH-720-A1 [A1] | – | – | – | – | Lon-81 [B1] | – |

| Manufacturers | AWS-ASTM Classification | E9011 | E9013 | E9015 | E9016 | E10010 | E10011 | E10013 | E10015 | E10016 | E12015 | E12016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | – | – | – | Airco 354 [B2] | – | – | Airco 190 | – | Airco 394 [B1 351 [B3] | Airco 352 | – |
| Alloy Rods Co. | | – | – | – | Atom Arc 9016 CM [B3] | – | – | – | – | Atom Arc 10018 MA | – | Atom Arc 120 M MA [C] |
| Arcos Corp. | | – | – | Chromend 2MS, Manganend 1M, Chromend 2M [B3] | Ductilend 90, Chromend 2 MA [B3] | – | – | – | Manganend 2M | Ductilend 110, Tensilend 100 | Tensilend 120 | – |
| Champion Rivet Co. | | – | – | Cloloy 2A, Cloloy 2A-A [B3] | – | – | – | – | Hy-Lo 2500 | – | – | – |
| General Electric Co. | | – | – | – | W-916A [B2] | – | – | W-1013A | – | W-1016A, W-1016C, W-1016B [B3] | W-1216A | – |
| Harnischfeger Corp. | | – | – | – | P&H 7, P&H 80C, 90 LE [B3], 100 LE [B3] | – | – | AB-4 [B3] | P&H 12 | AB 28, P&H 12-2, 90 LH2, CA 25 | P&H 13 | P&H 17 |
| Hobart Brothers | | – | – | – | Rocket LH 916 [B3] | – | – | – | – | Rocket LH 1016 | – | – |
| Lincoln Electric Co. | | – | – | – | – | – | – | Flaxweld 1 | – | – | – | – |
| Liquid Carbonic Corp. | | – | – | – | Liquid L-91 | – | – | Liquid L-90 | – | Liquid L-94 | – | – |
| Marquette Mfg. Co., Inc. | | – | – | – | – | – | – | No. 110 | – | – | – | – |
| McKay Co. | | – | – | – | – | – | – | – | – | Phurallov 100 AC | – | Phurallov 120 AC |
| Metal & Thermit Corp. | | Mutex 2111 | – | Mutex Cloloy 2A A [B3], | Mutex 2116 | – | – | – | – | Mutex A80, 4216, HTS-230 | Mutex HTS-250 | – |
| Morris, Wheeler & Co. | | Mor Weld 974 | – | Mor Weld 87 | Mor Weld 87 AC, 87 B1 AC [B1], 87 B2 AC [B2], 87 B3 AC [B3] | Mor Weld 785 | Mor Weld 884 | Mor Weld 78 | Mor Weld 88 | Mor Weld 98 AC | Mor Weld 89 | Mor Weld 89 AC |
| National Cylinder Gas Co. | | – | – | – | Sunweld 9016 [A1] | – | – | – | – | – | – | – |
| Reid-Avery Co. | | Raco 9011 [B2] | Raco 9013 [B2] | Raco 9015, 9015 [B2, C1, C2] | Raco 9016, 9016 [B2, C1, C2] | Raco 10010 [B3] | Raco 10011 [B3] | Raco 10013 [B3] | Raco 230, 10015-B3 [B3] | Raco 10016, 10016-B3 [B3] | Raco 260 | Raco 1267 |
| A. O. Smith Corp. | | – | – | – | SW-90 [B2], SW-89 [B3] | – | – | SW-98 [B2] | – | SW-100 | SW-120 | – |
| Southern Oxygen Co. | | E9011, E9011 [A1, B1, B2, B3] | E9013, E9013 [B1, B2, B3] | E9015, E9015 [A1, B1, B2, B3, C1, C2] | E9016, E9016 [A1, B1, B2, B3, C1, C2] | E10010, E10010 [A1, B1, B2, B3] | E10011, E10011 [A1, B1, B2, B3] | E10013, E10013 [B1, B2, B3] | E10015, E10015 [A1, B1, B2, B3, C1, C2] | E10016, E10016 [A1, B1, B2, B3, C1, C2] | – | – |
| Westinghouse Elec. Corp. | | – | – | – | Lon-82 [B2] | – | – | – | – | Lon-83 [B3] | – | – |

*Where a bracket [ ] does not follow the brand name, the electrode is an E7010, E7011, etc. The letters in the brackets indicate chemical requirements in accordance with the specifications such as E7010-A1, E7011-B1, etc.

## MILD STEEL *Electrodes*

*See Tentative Specifications for Mild Steel Arc-Welding Electrodes (AWS A5.1-55; ASTM A233-55)*

| Manufacturers | AWS-ASTM Classification | E4510 | E4520 | E6010 | E6011 | E6012 | E6013 | E6015 | E6016 | E6020 | E6024 | E6027 | E6030 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Airco 41, 63 | – | Airco 78E, 78 | Airco 230 | Airco 387, 323 | Airco 90, 90A, 90B | – | Airco 312 | Airco 335, 81, 306 | Easyarc 12 | – | – |
| Allied Weld-Craft, Inc. | | Arc Craft "B" | – | Arc Craft 55 | – | Arc Craft 70 | Arc Craft 77 | – | – | Arc Craft 60 | – | – | – |
| Amer. Chain & Cable Co., Inc., Page Steel & Wire Div. | | Page B Rust Line Coated | – | – | – | – | – | – | – | – | – | – | – |
| Auto Arc-Weld Mfg. Co. | | – | #66, #77 | – | – | – | – | – | – | – | – | – | – |
| Canadian Liquid Air Co., Ltd. | | LA 50-15 | – | LA 6010 | LA 6011 | LA 6012 | LA 6013 | – | LA 7016, 7016 P | LA 6020 | LA 6024 | – | – |
| Champion Rivet Co. | | Sobrial | Speed No. 44 | Blue Devil | Bluedot | Gray Devil, Gray Devil #7 | Graydot, Tan Devil | – | – | Black Devil | Speedenion-24 | – | Red Devil |
| General Electric Co. | | Type F, Type L | – | W-610A, W-610B, Strikeasy 610 | W-611A | W-612A, W-612B, W-612G | W-613A, W-613F | – | W-616A | W-620A, W-620B, W-620C | Strikeasy 624 | – | – |
| Hornischfeger Corp. | | Washcote | – | AP, APV | AC-1 | FF, FFA, WE-8 | AC-3, SM, DH6 | – | 78, A-1 | DH7, DH8 | DH5 | – | – |
| Hobart Brothers | | Sunkote | – | No. 10 | No. 335 | No. 12, 77, 212 | No. 447, 313, 15, Rocket 14 | – | – | No. 111 | Rocket 24 | Rocket 27 | – |
| Lincoln Electric Co. | | Stable Arc | – | Fleetweld 5, 5P, Lightweld | Fleetweld 35, 180 | Fleetweld 7, 72 | Fleetweld 37, Improved Fleetweld 47, Flaneweld 2 | – | Shieldarc 1-70, Jetweld LH-70 | – | Jetweld 1 | Jetweld 2 | – |
| Liquid Carbonic Corp. | | – | – | 250 N | L-30 | L-67 | L-73E | – | L-12 | L-15 | Kestarc | – | – |
| Marquette Mfg. Co., Inc. | | No. 101 | – | No. 105 | No. 130 | No. 120 | No. 151, 141, 5013 | – | – | No. 115 | No. 12 | – | – |
| McKay Co. | | 21 | 3 | 15, 15D | 11 | 116, 17 | 28 | – | – | 16 | Comet Arc | – | 18 |
| Metal & Thermit Corp. | | – | – | Murex B | Murex A | Murex Genex M, Genex, N-13 | Murex U, U-10 | – | Murex eHT | Murex EHF, D | Murex Speedex | – | – |
| Morris, Wheeler & Co. | | Mor Weld 51 | Mor Weld 57 | Mor Weld 65 | Mor Weld 64 | Mor Weld 67 | Mor Weld 63 | – | – | Mor Weld 66 | Mor Weld 624 | Mor Weld 627 | Mor Weld 68 |
| National Cylinder Gas Co. | | Sureweld 30S | Sureweld 30XL | Sureweld B | Sureweld CB | Sureweld N, NM, G | Sureweld C, CN, CE | – | – | Sureweld FD | Sureweld 6024 | Sureweld 6027 | – |
| Pacific Welding Alloys Mfg. Co. | | Pacific E4510 | – | Pacific E6010 | Pacific E6011 | Pacific E6012 | Pacific E6013 | – | – | Pacific E6020 | – | – | – |
| Reid-Avery Co. | | Raco Blue Label | Raco Type D, Type M | Raco 7 | Raco 11 | Raco 8 | Raco 13 | Raco 6015 | Raco 6016 | Raco 20 | Raco 624 | Raco 627 | Raco 5 |
| Shober Sales, Inc. | | – | – | 37 | 11, 33 | 34 | 35 | – | 4016 | – | 36 | – | – |
| A. O. Smith Corp. | | – | – | SW-10 | SW-14 | SW-11, SW-12, SW-17, SW-29 | SW-15, SW-16, SW-15FF | SW-64 | SW-65 | SW-35 | SW-44 | – | – |
| Southern Oxygen Co. | | – | – | E 6010 | E 6011 | E 6012 | E 6013 | E 6015 | E 6016 | E 6020 | E 6024 | E 6027 | – |
| Standard Steel & Wire Co. | | Prescote | – | – | – | – | – | – | – | – | – | – | – |
| Steel Co. of Canada, Ltd. | | Stelco Electrod 4, 4 FCW | – | Stelco Electrod 704, 704 D, 610 P | Stelco Electrod 504, 504 D | Stelco Electrod 604 | Stelco Electrod 404 | – | Stelco Electrod 616 S | Stelco Electrod 804 | Stelco Electrod 624 | – | Stelco Electrod 904 |
| U. S. Electric Welder Corp. | | – | – | – | – | – | U. S. No. 500 | – | – | – | – | – | – |
| Westinghouse Electric Corp. | | Sutonal-18 | – | KL-610 | ACP-611 | FP-612, FP2-612 | SW-613, SW2-613, SW3-613 | – | Conf-616 | DH-620 | ZIP-24 | ZIP-27 | – |

## IRON and STEEL *Welding Rods*

*See Tentative Specifications for Iron and Steel Gas-Welding Rods (AWS A5.2-46; ASTM A251-46)*

| Manufacturers | AWS-ASTM Classification | GA 65 | GA 60 | GA 50 | GB 65 | GB 60 | GB 45 |
|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | – | Airco No. 1, 4, 11 | Airco No. 7 | Airco No. 5 | – | – |
| Amer. Chain & Cable Co., Inc., Page Steel & Wire Div. | | Page 3½% Nickel | Page Hi-Tensile "M" | Page "C" Gas | Page 3½% Nickel | Page Hi-Tensile "M" | Page "C" Gas |
| Canadian Liquid Air Co., Ltd. | | – | LA Superweld | "Hercules" Iron | – | LA Superweld | "Hercules" Iron |
| Champion Rivet Co. | | – | Hi-Test Gas Rod | Low Carbon Coppercoated | – | Hi-Test Gas Rod | – |
| General Electric Co. | | – | – | Type G | – | – | – |
| Hobart Brothers | | – | 907 | sub | – | – | – |
| Linde Air Products Co. | | Oxweld 32 CMS | Oxweld 1 (HT) | Oxweld 1 (HT) | Oxweld 32 CMS, Oxweld 1 (HT) | Oxweld 32 CMS, Oxweld 1 (HT) | Oxweld 7 |
| Marquette Mfg. Co., Inc. | | – | No. 3 | No. 2 | – | – | No. 1 |
| McKay Co. | | – | 81 | 80 | – | 82 | 83 |
| Metal & Thermit Corp. | | – | M & T #3 | M & T #2 | – | M & T #3 | M & T #1 |
| Morris, Wheeler & Co. | | – | Mor Weld 45 | – | – | Mor Weld 45 | Mor Weld 41, 47 |
| National Cylinder Gas Co. | | NCG No. #5 | NCG No. #6 | NCG No. #2 | NCG No. #5 | NCG No. #6 | NCG No. #1 |
| Reid-Avery Co. | | – | Raco Hi Tensile | Raco Mild Steel | – | Raco Hi-Tensile | Raco Red Label |
| Shober Sales, Inc. | | – | #1 Hi-Test | – | – | – | #7 Copper-Cote |
| Southern Oxygen Co. | | – | GA 60 | GA 50 | – | GB 60 | – |
| Standard Steel & Wire Co. | | – | High Test | – | – | High Test | A |

## TUNGSTEN *Electrodes*

*See Tentative Specifications for Tungsten Arc-Welding Electrodes (AWS A5.12-55, ASTM B297-55)*

| Manufacturers | AWS-ASTM Classification | EWP | EWTh-1 | EWTh-2 | EWZr |
|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Airco Pure-Tungsten | Airco Thor-Tung (1%) | Airco Thor-Tung (2%) | Airco Zirconium Tungsten |
| Cleveland Tungsten, Inc. | | Cleve-Tung Pure | Cleve-Tung R.F. | Cleve-Tung S.K. | – |
| General Electric Co. | | Hi-Purity | 1% Thoriated | 2% Thoriated | – |
| Linde Air Products Co. | | Heliarc Electrodes Pure Tungsten | Heliarc Electrodes Tung. 1% Thoriated | Heliarc Electrodes Tung. 2% Thoriated | – |
| Morris, Wheeler & Co. | | Mor Weld 400 | Mor Weld 401 | Mor Weld 402 | – |
| North American Philips Co., | | Elmet Pure | Elmet 1% Thoriated | Elmet 2% Thoriated | – |
| Sylvania Electric Products, Inc. | | Purotung | 1% Thoriated | 2% Thoriated | Zirtung |
| Westinghouse Electric Corp. | | Pure Tungsten | Thoriated Tungsten 1% | Thoriated Tungsten 2% | – |

## Bare ALUMINUM *Welding Rods and Electrodes*

*See Tentative Specifications for Aluminum and Aluminum-Alloy Welding Rods and Bare Electrodes (AWS A5.10-54, ASTM B285-54)*

| Manufacturers | AWS-ASTM Classification | R-996A | E-996A | R-990A | E-990A | R-C4A | R-CN42A | R-C541A | E-C541A | R-G1A | E-G1A | R-GM50A | E-GM50A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | – | – | Arco 25 | Arcomatic A2 | – | – | – | – | – | – | – | Arco 5356 Arcomatic A56 |
| Aladdin Rod & Flux Mfg. Co. | | – | – | Aladdin 2-5 | Aladdin 2-5 | – | – | – | – | – | – | – | |
| All-State Welding Alloys Co., Inc. | 1160 | 1160-Spooled | 1100 | 1100-Spooled | 195 | 140 | – | – | 5654 | 5654-Spooled | 5356 | 5356-Spooled |
| Aluminum Co. of America | 1060 Welding Rod | 1060 L.G. Electrode | 1100 Welding Rod | 1100 L.G. Electrode | 214 Welding Rod | 142 Welding Rod | 2014 Welding Rod | 2014 L.G. Electrode | 5654 Welding Rod | 5654 Welding Rod | 5356 Welding Rod | 5356 L.G. Electrode |
| Aluminum Wire Products Co., Inc. | – | – | AWP-1100 | – | AWP-195 | AWP-142 | AWP-2014 | – | AWP-5654 | – | AWP-5356 | – |
| Arcos Corp. | – | – | Alumar 25 | Alumar 25 | – | – | – | – | – | – | Alumar 560 | Alumar 560 |
| Canadian Liquid Air Co., Ltd. | – | – | LA 25 Aluminum | – | – | – | – | – | – | – | LA 560 Aluminum | |
| Champion Rivet Co. | – | – | 2-S | 2-S | – | – | – | – | – | – | C56-S | C56-S |
| Collins-Edmonds, Inc. | – | – | C-E 2-S | C-E 2-S | – | – | – | – | C-E 5056 | C-E 5050 | C-E 5356 | C-E 5356 |
| General Electric Co. | – | EA-1160 | – | EA-1100 | – | – | – | EA-2014 | – | EA-5654 | – | EA-5356 |
| Kaiser Alum. & Chemical Corp. | – | – | King 1100 | King 1100 | – | – | – | – | – | – | – | – |
| Linde Air Products Co. | – | – | Oxweld 64 | Oxweld 64 | – | – | – | – | – | – | Oxweld 67 | Oxweld 67 |
| McKay Co. | – | – | 7 | – | – | – | – | – | – | – | 56 | – |
| Metal & Thermit Corp. | – | – | 25 | 25 | – | – | – | – | – | – | – | – |
| Morgan Alum. Welding Rod Co. | Marco AL-25 | Marco AL-25 | Marco AL-25 | Marco AL-25 | Marco 195 | Marco 140 | – | – | – | – | Marco AL-C560 | Marco AL-C560 |
| Morris, Wheeler & Co. | – | – | 22 | 22 | – | – | – | – | – | – | – | – |
| National Cylinder Gas Co. | No. 3130 | No. 201 | – | – | – | – | – | – | – | – | – | No. 221 |
| Reid-Avery Co. | – | – | Raco AL-25 | – | – | – | – | – | – | – | Raco AL-560 | – |
| Reynolds Metals Co. | 1160 | 1160 | 1100 | 1100 | – | – | 514 | 2014 | 5050 | 5050 | – | – |
| Wooldridge Aluminum Welding Products | – | – | Almaz Pure 2-S | – | – | – | – | – | – | – | – | – |

| Manufacturers | AWS-ASTM Classification | R-GR20A | E-GR20A | R-GR40A | E-GR40A | R-MG11A | E-MG11A | R-S5B | E-S5B | R-SC51A | R-SG70A | R-ZG61A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | – | – | – | Arco 5154 Arcomatic A54 | – | – | Arco 35 | Arcomatic A43 | Arcomatic A55 | – | – |
| Aladdin Rod & Flux Mfg. Co. | | – | – | – | – | – | – | Aladdin 43-S | – | – | – | – |
| All-State Welding Alloys Co., Inc. | 5052 | 5052-Spooled | 5154 | 5154-Spooled | 3003 | 3003-Spooled | 4043 | – | 355 | 356 | – |
| Aluminum Co. of America | 5052 Welding Rod | 5052 L.G. Electrode | 5154 Welding Rod | 5154 L.G. Electrode | 3004 L.G. Electrode | – | 4043 Welding Rod | 4043 L.G. Electrode | 355 Welding Rod | 356 Welding Rod | – |
| Aluminum Wire Products Co., Inc. | AWP-5052 | – | AWP-5154 | – | AWP-3004 | – | AWP-4043 | – | AWP-355 | AWP-356 | – |
| Arcos Corp. | Alumar 525 | Alumar 525 | Alumar 540 | Alumar 540 | – | – | – | – | Alumar 355 | – | – |
| Canadian Liquid Air Co., Ltd. | – | – | – | – | – | – | LA 335 Aluminum | LA 335 Aluminum | – | – | – |
| Champion Rivet Co. | 52-S | 52-S | A-545 | A-545 | – | – | 43-S | – | 355 | – | – |
| Collins-Edmonds, Inc. | C-E 5052 | C-E 5052 | C-E 5154 | C-E 5154 | – | – | C-E 4043 | C-E 4043 | – | – | – |
| General Electric Co. | – | EA-5052 | – | EA-5154 | – | EA-3004 | EA-4043 | – | – | – | – |
| Kaiser Alum. & Chemical Corp. | – | – | – | King 5154 | – | – | King 4043 | – | – | – | – |
| Linde Air Products Co. | – | – | Oxweld 64 | Oxweld 64 | – | – | Oxweld 23 | – | – | – | – |
| Marquette Mfg. Co., Inc. | – | – | – | – | – | – | No. 70 | – | – | – | – |
| McKay Co. | 52 | – | 54 | – | – | – | 43 | – | – | – | – |
| Metal & Thermit Corp. | – | – | A545 | A545 | – | – | 435 | – | 355 | – | – |
| Morgan Alum. Welding Rod Co. | Marco AL-525 | Marco AL-525 | Marco AL-540 | Marco AL-540 | – | – | Marco AL-435 | – | Marco AL-356 | Marco AL-356 | Marco AL-140 |
| Morris, Wheeler & Co. | – | – | – | – | – | – | 23 | – | – | – | – |
| National Cylinder Gas Co. | – | – | – | No. 2331 | – | – | No. 3112 | – | – | – | – |
| Reid-Avery Co. | – | – | Raco AL-545 | – | – | – | Raco AL-435 | – | – | – | – |
| Reynolds Metals Co. | 5052 | 5052 | 5154 | 5154 | – | – | – | – | – | – | – |
| Wooldridge Aluminum Welding Products | – | – | – | – | – | – | Almaz 5% Silicon | – | – | – | – |

## Covered NICKEL ALLOY *Electrodes*

*See Tentative Specifications for Nickel and Nickel-Base Alloy Covered Welding Electrodes (AWS A5.11-54, ASTM B295-54)*

| Manufacturers | AWS-ASTM Classification | E3N10 | E3N11 | E3N12 | E3N14 | E3N19 | E3N1B | E4N1B | E3N1C | E4N1C | E4N10 | E4N11 | E4N12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All-State Welding Alloys Co., Inc. | | All-State No. 16 | All-State No. 9 | All-State No. 18 | – | – | – | – | – | – | – | All-State No. 14 | – |
| Arcos Corp. | | Monend 806 | – | Chromend 14-75 | – | – | Chromend B | Chromend B | Chromend C | Chromend C | Monend 806 | – | Chromend 20/80 |
| General Electric Co. | | ENi-60 | ENi-61 | ENi-62 | ENi-64 | ENi-69 | – | – | – | – | – | – | – |
| Haynes Stellite Co. | | – | – | – | – | – | Hastelloy Alloy B | Hastelloy Alloy B | Hastelloy Alloy C | Hastelloy Alloy C | – | – | – |
| International Nickel Co., Inc. | | Inco "133" Monel | Inco "131" Nickel | Inco "230" Inconel | Inco "134" "K" Monel | Inco "139" Inconel "X" | – | – | – | – | Inco "140" Monel | Inco "141" Nickel | Inco "142" 80/20 Ni. Cr. |
| Reid-Avery Co. | | – | Hacolloy Nickel | – | – | – | – | – | – | – | – | – | – |

## Covered ALUMINUM *Electrodes*

*See Tentative Specifications for Aluminum and Aluminum Alloy Metal Arc Welding Electrodes (AWS A5.3-43; ASTM B184-43)*

| Manufacturers | AWS-ASTM Classification | A1-2 | A1-43 |
|---|---|---|---|
| Air Reduction Sales Co. | | | Aircomatic 43 |
| Aladdin Rod & Flux Mfg. Co. | | Aladdin 6-43 | Aladdin 6-43 |
| Allied Weld-Craft, Inc. | | Weld-Craft E-43 | Weld-Craft E-43 |
| All-State Welding Alloys Co., Inc. | | All-State No. 2 (Cl. C) | All-State No. 12 |
| Alum. Wire Products Co., Inc. | | ABI-A-43 Electrode | ABI-A-43 Electrode |
| American Welding Alloys Corp. | | – | AWA-43 Aluminum Electrode |
| Arcos Corp. | | Alumweld 43 | Alumweld 43S |
| Canadian Liquid Air Co., Ltd. | | – | LA Aluminum |
| Champion Rivet Co. | | AL-43 | AL-43 Aluminum |
| Hobart Brothers | | – | Aluminum |
| Lincoln Electric Co. | | – | Aluminum |
| Marquette Mfg. Co., Inc. | | – | No. 75 |
| Metal & Thermit Corp. | | AL-43 | AL-43 |
| Morgan Aluminum Welding Rod Co. | | Morgan AL-43 | Morgan AL-43 |
| Morris, Wheeler & Co. | | – | Mor-Weld 43 |
| National Cylinder Gas Co. | | – | Sunweld 43S |
| Sightmaster Corp. | | Sightmaster | – |
| Woolridge Aluminum Welding Products | | – | Bridge Aluminum Arc Welding Electrode |

By publication of these comparison charts, the AMERICAN WELDING SOCIETY does not insure anyone utilizing the charts against liability arising from the use of such charts. A publication of comparison charts by the AMERICAN WELDING SOCIETY does not carry with it any right to make, use or sell any patented items. Each prospective user should make independent investigations.

## COPPER ALLOY *Electrodes*

*See Tentative Specifications for Copper and Copper Alloy Welding Electrodes (AWS A5.6-53, ASTM B225-53)*

| Manufacturers | AWS-ASTM Classification | ECu | ECuSi | ECuSn-A | ECuSn-C | ECuNi | ECuAl-A1 | ECuAl-A2 | ECuAl-B |
|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Aircomatic A145 | Aircomatic A110 | – | Aircomatic A107 | | Aircomatic A108 | Arco 100, Aircomatic A100, A101 | Arco 116, Aircomatic A161 |
| All-State Welding Alloys Co., Inc. | | All-State No. 76 | | | All-State No. 74 | | | | |
| Alloy Rods Co. | | – | | | Bronze-Arc C | | | | |
| Ampco Metal, Inc. | | – | | | Ffos Trade | | | Ampco-Trade 10 | Ampco-Trade 160 |
| Arcos Corp. | | – | | | – | Tyconi | | – | |
| Bridgeport Brass Co. | | – | Silicon Bronze 656 | | | | | | |
| Champion Rivet Co. | | – | | | Bronze Devil | | | | |
| Hobart Brothers | | – | 430 | | Aristarc | | | | |
| International Nickel Co., Inc. | | | | | | Inco "A" | | | |
| Lincoln Electric Co. | | – | | | Aristarc | | | | |
| Linde Air Products Co. | | Sunweld 63 | Sunweld 76 | | – | – | Sunweld 62 | Sunweld AT-10 | – |
| Marquette Mfg. Co., Inc. | | – | No. 81 | | – | – | – | | – |
| Metal & Thermit Corp. | | – | – | | Murex PS-17 | – | | | Murex AB-16 |
| Morris, Wheeler & Co. | | Mor-Weld 36 | 38 | Mor-Weld 30-A | – | – | – | – | – |
| National Cylinder Gas Co. | | – | – | Sunweld 20S | – | – | – | – | – |
| Shober Sales, Inc. | | – | – | – | Shober Phos-Bronze | – | – | – | – |
| Southern Oxygen Co. | | ECu | ECuSi | – | – | ECuNi | – | – | – |

## COPPER ALLOY *Welding Rods*

*See Tentative Specifications for Copper and Copper-Alloy Welding Rods (AWS A5.7-52, ASTM B259-52)*

| Manufacturers | AWS-ASTM Classification | RCu | RCuSi-A | RCuSi-B | RCuSn | RCuNi | RCuZn-A | RCuZn-B | RCuZn-C | RCuZn-D | RCuAl-A1 | RCuAl-A2 | RCuAl-B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Reduction Sales Co. | | Arco Cu 116 | – | – | – | – | Arco No. 20 | Arco No. 22 | Arco No. 21 | – | – | – | – |
| All-State Welding Alloys Co., Inc. | | – | – | – | – | – | – | – | Low Fuming Bronze | – | – | – | – |
| American Brass Co. | | Ambrolite Rod-Cu 57 | Ambrolite 651 | – | Phosphor Bronze 534 | Cupro Nickel 502 | Tobin Bronze 421 | – | Ambrolite 853 (Low Fuming Bronze) | Tobin Bronze 670 | Ambrolite 854 | – | – |
| Ampco Metal, Inc. | | – | – | – | – | – | – | Ampco Braz No. 3 | – | – | – | Ampco-Trade 10 | Ampco-Trade 160 |
| Bridgeport Brass Co. | | – | Silicon Bronze 656 | – | – | – | Bronze 196 | Manganese 191 | No. 192 | Nickel Silver 149 | – | – | – |
| Canadian Liquid Air Co., Ltd. | | – | – | – | Oxweld | – | – | – | Aiten Super Bronze "FL" Bronze | – | – | – | – |
| Collins-Edmonds, Inc. | | C-E Deoxidized Copper | C-E 20 [illegible] | C-E 10 [illegible] | C-E RCuSn | C-E RCuNi | C-E RCuZn-A | – | C-E RCuZn-C | C-E RCuZn-D | C-E RCuAl-A1 | C-E RCuAl-A2 | C-E RCuAl-B |
| Hobart Brothers | | 102 | – | – | – | – | – | 314 | 412 | – | – | – | – |
| International Nickel Co., Inc. | | – | – | – | – | Inco "A" "61" | – | – | – | – | – | – | – |
| Linde Air Products Co. | | – | Sunweld 76 | – | – | – | – | – | Sunweld 76-M | – | – | – | – |
| Marquette Mfg. Co., Inc. | | – | – | – | – | – | – | No. 20 | No. 32 (Low Fuming Bronze 30) | No. 38 (Low Fuming Bronze 38) | – | – | – |
| Metal & Thermit Corp. | | – | – | – | – | – | Naval Brass | – | Low Fuming Bronze | – | – | – | – |
| Morris, Wheeler & Co. | | Mor-Weld 36 | 76 | – | Mor-Weld 30-A | – | 31 | – | Mor-Weld 34 | Mor-Weld 39 | – | – | – |
| Mueller Brass Co. | | – | – | – | – | – | No. 203, No. 206 | No. 241 | No. 245 | – | – | – | – |
| Reid-Avery Co. | | – | – | – | Reactive Phosphor Bronze | – | – | – | – | – | – | – | – |
| Revere Copper & Brass, Inc. | | Phosphor Deoxidized Copper 102, Silicon Deoxidized Copper 109 | Herculoy 535 | Herculoy 421 | – | – | Bronze 180 | – | 456 (Low Fuming) | – | – | – | – |
| Titan Metal Mfg. Co. | | – | – | – | – | – | Naval Bronze No. 60 | Naval Manganese Bronze No. 59 | Manganese Bronze No. 22, No. 78 | – | – | – | – |

# OUTSIDE FRAME SKELETON ON ALL-WELDED BUILDING GIVES CLEAR INNER AREA, CUTS COST

BY RAY ZEH

Arc-welded steel and plate glass construction, nested in a novel "inside-out" framing, lends rugged simplicity and structural acuity to the new Crown Hall at the Technology Center of Illinois Institute of Technology on Chicago's South Side (Fig. 1). The 220- x 120-ft single-story structure provides 26,400 sq ft of completely unobstructed main floor space with 19½-ft ceiling, plus equivalent area in a basement section. As one student observer remarked: "It makes a good place to be alone in a crowd."

Basic structural frame comprises four built-up plate girders with approximately 120-ft span and 6-ft deep webs. They are supported by eight 14 WF 84-pound columns, 28½ ft long, anchored to foundation piers. Hangers welded to the lower flange of the girders support eleven parallel rows of 16 WF 58-lb purlins. Steel roof deck, insulation and roof covering are laid over the upper flanges of the purlins, the roof deck being a metal type, 2½ in. thick. An acoustic ceiling is suspended from the lower flanges. Between are diagonal bracing rods, air-conditioning ducts, recessed lighting fixtures and utility lines. Top of the metal roof deck is 8 in. below the lower flange of the girder.

Around the walls are 8 WF 20-lb structural mullions, 26½ ft long and spaced on 10-ft centers. They are outside the window line, welded at the top to a 26-in. roof fascia plate, ⅜ in. thick; at floor level to a 15-in., 33.9-lb fascia channel; and at ground level to a 6- x 6- x ½-in. sill angle (Fig. 2). These three horizontal members, of butt-welded sections, run continuously around the building.

R. Zeh is District Engineer associated with The Lincoln Electric Co., Cleveland, Ohio.

Fig. 1 Main entrance to Illinois Tech's $750,000 Crown Hall, showing novel "inside-out" framing, with two of four main plate girders and columns, and intermediate outside structural mullions

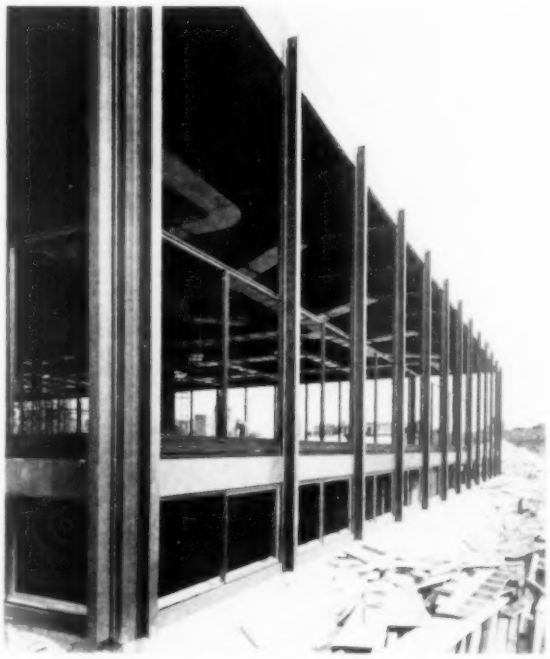

Fig. 2 Side elevation, with structural mullions in place, welded to roof fascia plate, to main floor fascia channel and to ground level sill angle. Note ducts hung between purlins inside

Plate-glass wall sections extend from the roof fascia plate to floor level, retained in welded-steel bar window frames. In each bay, the lower 7 ft of glass and the basement glass are in two vertical sections and, except at the entrance area, are sandblasted to diffuse light.

Plate girders and supporting wide-flange columns are spaced 60 ft apart, the outer units being 20 ft inside from either end of the building. The girders have top and bottom flanges of 1½-in. plate, 12 in. wide, for the outer 17 ft at either end. The plate changes to 18 in. in width and 2 in. in thickness for the next 14½ ft on either side of the centerline, while the center portion increases in thickness to 2⅜ in. The girder was designed with a camber of 2⅜ in. at center, which deflected to horizontal under dead load.

Fig. 3 Two crawler cranes hoist a spliced 120-ft welded plate girder onto its supporting columns. Single-story building is 220 x 120 ft, required only 285 tons of structural steel

Flanges are shop welded with a 60° V-groove, the thicker plate being beveled down where it meets a thinner flange. Girders were fabricated in halves and shipped to the erection site where field splices were made. Two crawler cranes hoisted the assembled girder to place on the columns, as illustrated (Fig. 3).

Field splice welds in girders are 1 ft off the centerline, U-grooves being shop cut in the webs for maximum resultant weld thickness. Detail of a typical splice in a span is shown in Fig. 5.

Web stiffener plates are welded along the girder on both sides, 5 ft apart, 23 in all. Directly above the purlin hangers, these stiffeners are 5 1/2 x 3/8-in. plate; between them, smaller 2 1/2 x 3/8-in. plate sections are used. Stiffener plates are beveled at the lower ends for 45° groove welds. Joints with the web and upper flange are 1/4-in. fillet welds on both sides.

Fig. 4 Detail of main girder to column connection, typical of the clean, smooth weld lines

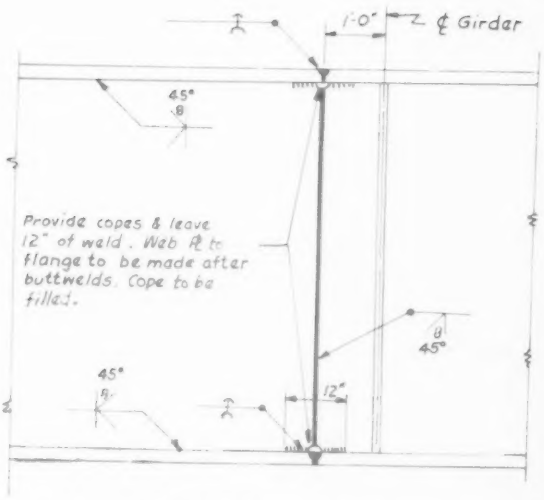


Fig. 5 Sketch of field splice made 1 ft off center of 120-ft girder. Web plate is 1/2 in. thick, 6 ft deep; flanges, 2 1/2 in. thick. Deep-groove butt welds are made on flanges and web

It is appropriate that the building houses the Institute's Departments of Architecture, Design and Planning, since it embodies the most advanced concepts of Ludwig Mies van der Rohe, internationally famed architect, who calls Crown Hall "the clearest structure we have done, the best to expose our philosophy." His ingenious idea of an external frame skeleton has long been on his sketch pads, but this is its first evolution. Associate architects-engineers were Pace Associates; structural engineers, Frank J. Kornacker & Associates; structural fabricator, Hansell-Elcock Co., all of Chicago, Ill.

Since the building qualified under the Chicago building code as a single-story design, the encumbrances of concrete fireproofing around structurals were not a matter of concern and, fortunately, the structural steel could be left in full view. Structural requirements, incidentally, were 285 tons, amounting to about $270 a ton.

It would be difficult to enumerate all the field-welding operations involved in the erection sequence. Suffice it to say that virtually every single connection from window mullions to girders is are welded. Even where erection bolts were necessary, as in locating girders on column, when the joint was completed, bolts were cut out, the holes plug welded and ground smooth. (Fig. 4.)

A 60- x 24-ft entrance terrace, for example, comprises a grid of all-welded 12 WF 50-lb members, providing, after surfacing, an ample plaza for relaxation or a reviewing stand.

A low penthouse, about 40 ft square and 6 ft high, on the roof houses mechanical equipment. Its roof is flush with the top flanges of main girders.

Crown Hall, in the opinion of many qualified architects—some not too prone to encomiums—represents a masterful, yet pleasantly restrained, symphony in welded structural steel.

# FLAME CAMBERING OF BEAMS FOR BRIDGES

BY A. H. YOCH

Many of the facilities of a modern shipyard are adapted to a wide variety of production work not associated with the construction of ships. An example of this diversification at New York Shipbuilding Corp., Camden, N. J., is the flame cambering of beams for bridges—part of the nation's highway improvement program.

"Camber" in a beam is a rising or convex-upward curvature that is introduced during fabrication, principally to compensate for the sag or deflection under the weight of the beam and any loads it must carry. Sometimes the curvature is made sufficient to leave a substantial amount of camber after deflection to fit a vertical curvature in the roadway.

In determining the amount of camber desired in a beam, the effects of future welding operations are also considered. Mill tolerance and practice will not meet camber specifications, and ship equipment is not available for cold bending of these large sections. The camber required can vary from less than an inch to six inches in beams running from 40 to 100 ft in length.

**A. H. Yoch** is Process Engineer associated with Air Reduction Sales Co., Philadelphia District.

Fig. 1 Close-up of carrying machine mounted with three torches for flame cambering of beams by progressive heating to obtain required "rise" in beam

Flame cambering is accomplished by running heating torches at controlled speeds and heats along the flange of the beam. Accuracy of camber can be obtained within the nearest $\frac{1}{4}$ in.

At New York Ship, flame cambering is accomplished with a carrying machine on which three torches are mounted, fitted with special heating tips (Fig. 1). The unit is started on top of the flange of an upright beam and run continuously over the area specified, sometimes the full length, other times a localized area. Progressive heating speeds of 11 to 26 ipm are used. Two runs in this range are more successful than a single run at slower speeds. It is generally necessary to obtain a rise during heating of two to three times the camber desired. The amount the beam rises when heated thus can be used as a guide for the approximate camber that will remain after the beam has cooled. Temperatures on the flange vary from 250 to 300° F.

Final camber cannot be measured until the beam has thoroughly cooled (Fig. 2). Experience in setting speeds to give a uniform rise from the heating increases the percentage on the number of beams that are successfully cambered on the initial run.

An asbestos baffle is mounted on front of the carrying machine to protect it from heat. When in operation, an asbestos cloth is also laid over this baffle and the front of the machine.

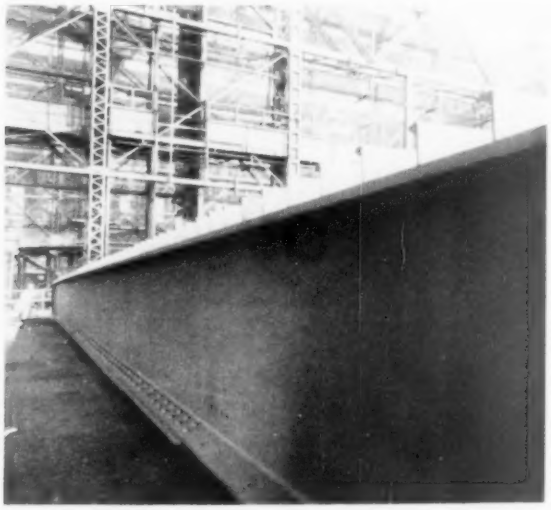

Fig. 2 Finished camber of beam

# SEMIAUTOMATIC WELDING LARGE BRIDGE MEMBERS

The American Bridge Division, U. S. Steel Corp., makes extensive use of submerged-arc welding in fabricating large members for the new Carquinez Bridge in California. Nearly 30,000,000 lb of steel, all shop welded, will be used in the bridge. Much of it is high strength USS "T-1" and "Tri-Ten."

Depending on size and joint design, full automatic, or either mechanized or manual semiautomatic equipment may be employed (Figs. 1 and 2). Material thicknesses range from $\frac{3}{8}$ to 3 in. and joints include bevelled fillets for full penetration, square-butt fillets and open corners. The relatively few butt joints on the job are manually welded.

American Bridge uses a unique mechanized semiautomatic welder on corner joints, mounted on a special carriage (Fig. 1). To adapt the welder, they removed the wire reel case and attached the reel directly to the carriage. A large clamp holds the flux cone and an additional hopper serves as a reservoir for extra flux. The carriage straddles the corner with idler wheels on one side and drive rolls on the other. Parts from a machine cutting buggy provide adjustments for centering the cone over the work and controlling its height above the work. Cables from the 600-amp welding generator provide d-c welding current and control power for the welder unit. A third line to the carriage supplies ac for the travel carriage motor.

The mechanized unit welds $\frac{3}{8}$-in. open-corner fillets on the Carquinez job. Traveling at speeds exceeding 12 ipm, it makes welds 40 ft long without stopping. The planed edges of the joint are carefully fitted together and tack welded before automatic welding begins. Cranes place the large members in cradles which position the fillets for flat welding.

Manual semiautomatic equipment speeds welding on joints not readily adapted to full automatic equipment. It welds with the same speed and quality as the mechanized unit, but must stop every 12-15 ft to replenish the flux supply in the cone. American Bridge employs semiautomatic units on fillet welds, joining flanges to web sections on lighter H-section members. They position the H-sections in a cradle for flat welding. The operator simply rests an arm on the flange and moves the cone along over the joint. He makes $\frac{3}{8}$-in. fillet welds.

Based on a story by the Lincoln Electric Co., Cleveland, Ohio.

Fig. 1 Mechanized semiautomatic welder makes $\frac{3}{8}$-in. fillet welds at speeds in excess of 12 ipm; completes 40 ft of weld without stopping

Fig. 2 Manual semiautomatic welder combines speed of automatic welding with flexibility of manual welding; makes $\frac{3}{8}$-in. fillet welds at speeds exceeding 12 ipm as operator moves the cone over the joint

Both mechanized and manual semiautomatic units use $^{3}/_{32}$-in. continuous electrode drawn from a 60-lb coil and an agglomerated flux which pours from the cone container. For the "T-1" steel, a $^{1}/_{2}$% molybdenum, 70,000-psi tensile-strength electrode, while not equally the strength of the steel, provides sufficient strength to meet the shear-stress requirements of the fillet joints on which it is used. The State of California checked and approved all welding procedures used on the Carquinez Bridge job. The company welds the high strength steel in the same way they weld mild steel without any special heat treatment.

# RADIOISOTOPE CAPSULES SEALED BY REMOTE CONTROL WELDING

A new welding unit for sealing highly-radioactive materials in stainless-steel capsules was recently placed into operation at Oak Ridge National Laboratory, Oak Ridge, Tenn. The unit is remotely operated and uses an inert-gas-shielded arc-welding torch. In the initial production run at the laboratory, which Union Carbide Nuclear Co., Division of Union Carbide Corp., operates for the U. S. Atomic Energy Commission, thirty-four sources containing a total of 8000 curies of radioactive cobalt were sealed using this equipment.

Radioactive materials such as cesium-137, iridium-192 and cobalt-60, in multi-curie quantities, have been prepared in capsule form by the Radioisotope Department at the laboratory for some time, using such sealing methods as soldering and gasketing. However, numerous requests for radioactive sources to be used in high-temperature operations or in corrosive solutions necessitated the use of tungsten-arc welded stainless-steel jackets which would stand up under these conditions. The Radioisotope Department in cooperation with the Welding Laboratory of the Metallurgical Division of ORNL designed and fabricated this unit for this purpose.

The welding equipment consists of two portable units: a power supply unit and a remotely-operated assembly (Fig. 1). The power supply unit is of conventional design and includes a welding machine, control panel and motorized amperage control. The remotely-operated portion of the welding device, which is placed in a shield cell equipped with mechanical manipulators, consists of a two-piece stainless-steel frame, and motor-driven positioners for both the torch and containers. Controls for the motors are located outside the cell near a viewing window.

The present equipment was designed primarily for sealing cylindrical stainless-steel containers by means of end or side circumferential welds. Test welds were made on several sizes of containers for establishing the proper operating conditions for welding the radioactive sources. The test weld passed stringent tests on weld penetration and the sealed containers were shown to be leak-tight by the hot-water test.

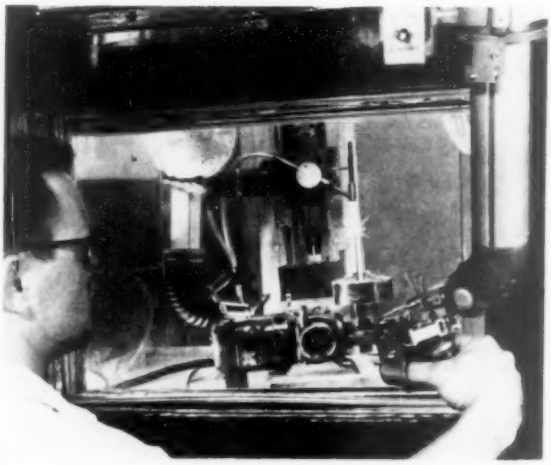

Fig. 1 Welding unit for sealing highly-radioactive materials in stainless-steel capsules in operation

Sealing radioactive sources by remote welding is considered to be an important development in the radioisotope program. Specifically, this technique will be used in sealing the large sources which will be produced in the nearly-completed Fission Product Pilot Plant at ORNL. These large sources will be used in medical and industrial applications. Also, radioactive materials for which there is no apparent immediate use will be sealed in multiple-walled, remotely weld-sealed metal containers for long-term safe storage.

Based on a story by Union Carbide Nuclear Co., New York, N. Y.

# WELDED STUDS FACILITATE FABRICATION OF FIELD-ASSEMBLED INSULATED ALUMINUM SANDWICH WALL

Savings of at least 30% in industrial wall installation costs were achieved with field-assembled insulated aluminum sandwich walls at three recently completed American Can Co. plant construction projects (see Fig. 1).

Based on a story by the Nelson Stud Welding Division, Gregory Industries, Inc., Lorain, Ohio.

Fig. 1 This field-assembled aluminum sandwich wall at this American Can Co. plant in San Antonio cost an estimated $15,000 less than other walls that could have been specified

Curtain walls of this type, held in place by end-welded shoulder-type studs, have been installed at American Can plants at savings of at least 30%

Fig. 2 Shoulder-type studs, end-welded to structural girts, are used to secure all elements of field-assembled insulated aluminum sandwich walls

These insulated sandwich walls, all of which were installed with shoulder-type studs, were bid as low as $1.22 per square foot, with an average bid price of $1.30 for standard wall cross sections.

All elements of the walls—aluminum or steel inner skin, Fiberglas insulation and exterior aluminum skin—were impaled and held in place on shoulder-type studs end-welded to structural girts (see Figs. 2 and 3). All of the work was handled from one side and there was no need to drill structural members nor to use tees or channel spacers. Several studs were end-welded per minute with a lightweight stud-welding gun.

The inner skin of 0.024-in. aluminum or 24-gage steel was first impaled over the studs and held in place with speed clips. The insulation, either 1 or $1\frac{1}{2}$ in. thick, was similarly impaled. Finally, the outer sheet, usually 0.032-in. ribbed embossed aluminum, was driven over the studs and aluminum caps were hammered

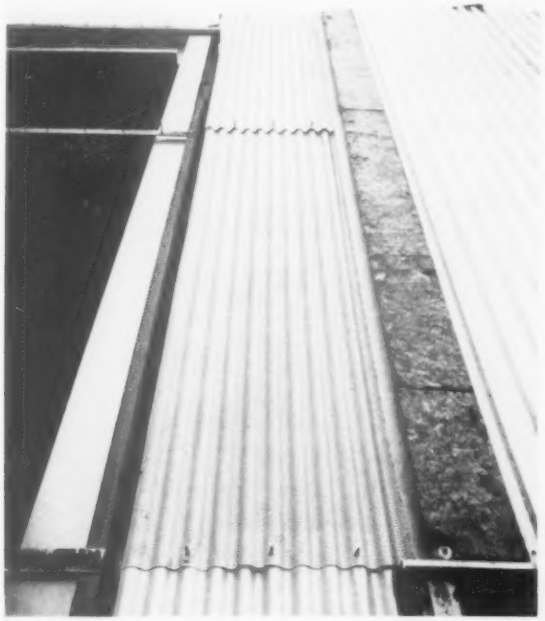

Fig. 3 All the elements of this new type of insulated aluminum sandwich wall are visible in this picture taken at the Hillside, N. J. coil processing plant and warehouse

At the left are shoulder-type studs, end-welded to structural girts. All the other elements of the walls—the aluminum inner skin, Fiberglas insulation and exterior aluminum skin—are impaled and held in place on the studs

lightly into position on the tips of the studs. Aluminum of the caps flowed into and gripped the serrations on the stud tips.

Bid price was $1.22 per square foot for installing curtain wall of this type at a new American Can coil processing plant and warehouse in Tampa, Fla. Approximately 18,000 stainless-steel studs in two sizes — $^{3}/_{16}$ in. in diameter by $1^{1}/_{4}$ in. long and $^{3}/_{16}$ by $^{3}/_{8}$ in. — were used to secure 30,000 sq ft of field-assembled sandwich wall.

Use of end-welded studs reduced by two-thirds the number of fasteners that would have been required if other erection methods had been employed, according to the contractors. On this job the inner skin was 24-gage flat galvanized steel sheet and the insulation was 1-in. thick.

On another American Can curtain wall job of 25,000 sq ft at San Antonio, Tex., bid price was $1.342 per square foot. Insulation was $1^{1}/_{2}$ in. thick and the inner skin was 0.024-in. corrugated embossed aluminum sheet. The exterior sheets, of 0.032-in. ribbed embossed aluminum, were 22 ft long and extended from the wainscoting to the eaves.

Taking all factors into consideration, the field-assembled sandwich wall on the San Antonio structure cost approximately $15,000 less than other walls that could have been used, it was estimated.

On a third American Can installation, a coil processing plant and warehouse at Hillside, N. J., a saving of 30% in labor erection cost was realized with curtain wall secured by studs. The alternative fastening procedure would have required subgirts and self-tapping screws.

More than 20,000 stainless-steel studs, $^{3}/_{16}$ by $2^{1}/_{4}$ in., were needed to secure the 41,500 sq ft of sandwich wall.

Even with special, extra-cost features, the bid price of this job was competitive with the standard grades of other types of curtain wall. Because the Hillside plant is located near residential areas, approximately 70% of the corrugated aluminum inner skin was perforated for acoustical purposes. In addition, a sheet of vapor barrier paper was installed between the insulation and the inner skin. Bid price was still only $2.00 per square foot.

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# ALL-WELDED ALUMINUM ALLOY YAWL

*Dyna* is a 58-ft all-welded aluminum-alloy yawl, first in America, built by the Burger Boat Co., Manitowoc, Wis.

Truly a beauty, her sleek aluminum hull is finished in glistening black, striped with gold. The mast is 72 ft tall and she will carry a sail area of 1604 sq ft. The interior is finished in English oak, while outside trim is in teak and the deck covered with fibreglass.

Based on a story by the Air Reduction Sales Co., New York, N. Y.

This all-welded aluminum pleasure craft was fabricated with the inert-gas-shielded metal-arc process for production speed and high-quality weld results.

Made possible by imaginative design and skilled application of the best production tools and techniques to the latest materials, *Dyna* is an impressive forerunner of things to come in the world of yachting. . .

Fig. 1 *Dyna*, a 58-foot all-welded aluminum alloy yawl

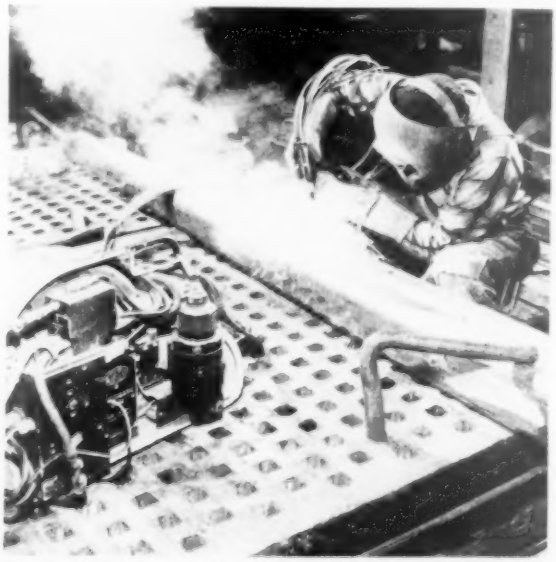

Fig. 2 Welding an aluminum spar for *Dyna* with the inert-gas-shielded metal-arc process

# PUT SOLDERING TO WORK . . . AND SAVE!

*Some helpful ideas on a useful process*

If you want to boost profits . . . and increase working efficiency in the bargain . . . try soldering. Today's new techniques and applications put soldering back in business on a wide range of jobs—jobs you now handle with other methods.

Here's a process that makes repairs quickly on all metals from A to Z . . . from aluminum to zinc. And it can save you dollars, too, on small fabrication work. Modern technology has discovered that you can even join glass or ceramic materials to some metals by a method quite similar to soldering. Why not check Table 1 and see just a few of the many places where soldering can help you? Some typical applications are shown in Figs. 1, 2, 3 and 6.

Table 1—Common Soldering Jobs

| | |
|---|---|
| Sheet Metal Work: | Plumbing: |
| Aluminum awnings | Copper tubing |
| Duct work | Iron fittings |
| Gutters and downspouts | Pipe fittings |
| Hole patching | Electrical Work: |
| Valleys and flashings | Air conditioning |
| Automotive Work: | Electric motors |
| Body work | Refrigerating equipment |
| Clips and lugs | Wire connections |
| Fuel and oil lines | Miscellaneous: |
| Gear casings | Machinery guards and shields |
| Leaky radiators | Soda fountain tubing |
| Truck and tractor repairs | Vats, tanks, kettles |

Based on a story by the Linde Co., New York, N. Y.

Fig. 1 Here a cap is being soldered on the brass part of a soda fountain cooling system

This is typical of the many repair jobs soldering can handle quickly, and at tremendous savings

Fig. 2 Stainless steel is easy to solder when properly cleaned

Use either a commercial paste or acid flux on this material. Here a handle is being soldered to a milker pail

Soldering means joining two metals at temperatures lower than the melting point of the base metals. Special jobs may require brazing. Here's a process similar to soldering—but, brazing is done at temperatures much closer to the melting point of the base metals.

When you have a repair job that requires joining two different materials (say copper and sheet metal), there's a good rule to remember: if the two metals can be soldered individually—they can be soldered together. This makes the list of soldering applications practically endless!

## Some Helpful Hints

You know that lead and tin are the ingredients in all but a few special solders. Silver solder—sometimes called hard solder—is in the special group. For most jobs, though, tin-lead solders are used.

Next time you select solder for a job, keep this in mind: the proportion of tin to lead determines the solder's melting point as well as its flow characteristics. The higher the tin percentage—up to 62%—the lower the melting point of the solder. Above 62% the melting point climbs.

Look at these examples. A 20% tin and 80% lead solder melts at 532° F; a 40% tin and 60% lead solder melts at 445° F; a 62% tin and 38% lead mixture melts at 361° F; while pure tin melts at 452° F.

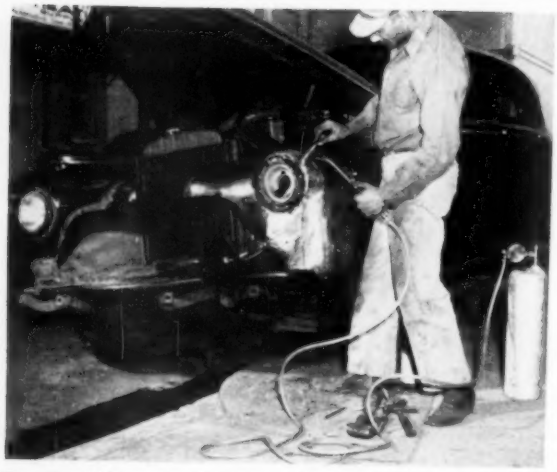

**Fig. 3** Filling car dents is easier if you keep the solder pasty

A wood paddle is sometimes helpful for working solder smooth. Finish the job with emery cloth; then clean, prime and paint

You'll find tin-lead solder comes in so many forms and types that you shouldn't have to "make-do." Besides having a complete choice of tin-lead compositions—special alloys, and fluxed or nonfluxed varieties—you can get solder in coils, sheets, powder, bars or even as paste. Choose what's best for your job . . . it will help your results.

## Tinning Makes the Difference

Don't forget, the secret of good soldering is in the tinning of the joint. And good tinning isn't possible if the base metal is not completely clean. Contrary to popular belief, flux is *not* a cleaner and will not make up for an improperly prepared surface. Remember, a soldered joint depends for its strength on slight solder penetration of the base-metal surface. That's why it's necessary to have surface areas spotless.

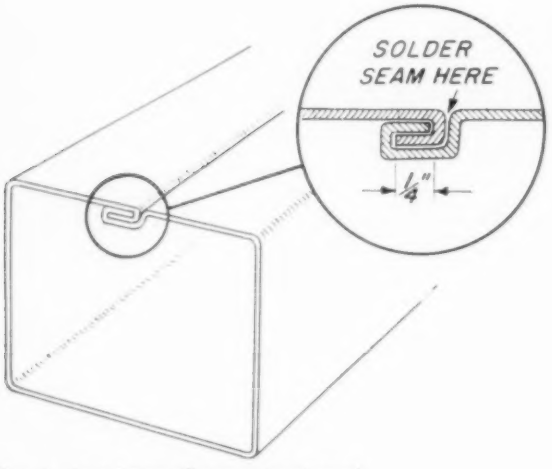


**Fig. 4** Lock joints offer greater strength

Soldering is faster when you run the flame a few inches ahead of the solder instead of heating and soldering a section at a time

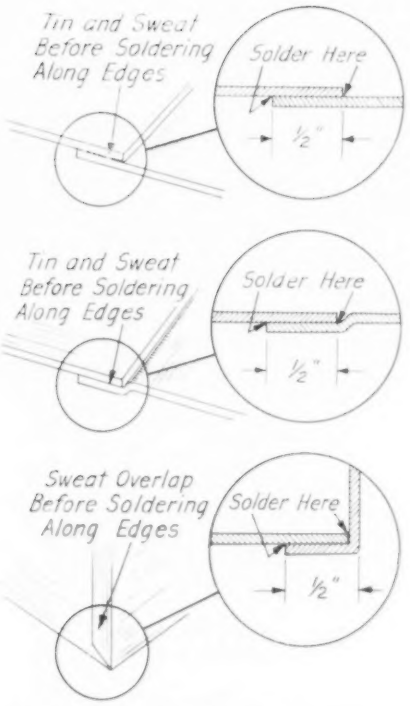


**Fig. 5** These three forms of lap joints are commonly used for soldering light metal parts

For added strength, rivet the joint together before soldering along the seams

In addition to removing paint, dirt and grease, you've got to clean off the oxide film that forms on the unprotected surface of your work. When you have removed this oxide, flux will prevent contamination while you solder.

Perhaps you know about the three different types of soldering fluxes. Each has particular advantages depending on the job. Acid fluxes—often called chloride fluxes—are highly active and best used on metals such as aluminum that form tough oxides. This type flux

**Fig. 6** When filling holes with solder, withdraw the flame and touch the solder to the hot metal

Remember, the hot point of the flame is just beyond the tip of the bright, white cone

leaves residue that sets up electrolytic action within the soldered joint, so use a different flux for your electrical connections.

Organic flux is milder than acid flux. The active material in this flux is dissolved in a petroleum base that is designed to burn up as you solder. This leaves little residue for you to clean.

Resin flux is less active than the others but you'll find it has one advantage. It's noncorrosive, and will not leave any harmful residue.

Why not select the exact flux for your job before you begin work. This will save you clean-up time, and it will improve your work. Table 2 can help you determine the flux that best suits your soldering needs.

### Improve Joint Strength

You've probably found that solder has little strength until it has completely cooled. A slight movement during cooling is usually sufficient to ruin a joint. This means you've got to resolder the piece and waste working time. You can avoid this by placing parts so they are held rigidly during soldering and cooling. If you place small, hard-to-handle parts in a box of sand they'll be held steady, and they'll cool correctly.

Soldered joints will support substantial weights for brief intervals—though they may fail if kept under constant load. It may surprise you to learn that a 50% lead, 50% tin soldered lap joint can support 5500 psi for a short time. However, for long periods it will hold only 235 psi.

Correct design can greatly improve joint strength. Be sure to consider this in all your jobs. Lock joints (Fig. 4) should be used where joint strain is high, but lap joints (Fig. 5) are usually adequate for light work.

Generally speaking, the higher the temperature of the base metal during soldering, the more deeply the solder will penetrate. But remember, the base metal should never be heated to the melting point. Constant stress or movement of soldered joints will lead to rapid failure. So, always brace large parts after installation.

Table 2—Soldering Fluxes

| *Metal* | *Flux to use* |
|---|---|
| Aluminum | Usually none required. Sometimes paraffin helps after surfaces have been tinned. |
| Block Tin | Rosin or zinc chloride. |
| Brass | Zinc chloride, rosin or sal ammoniac. |
| Cast Iron | Zinc chloride or sal ammoniac. Also zinc chloride added to melted tallow and heated until it foams and turns to reddish brown. |
| Copper | Zinc chloride, rosin or sal ammoniac. |
| Gun metal | Zinc chloride, rosin or sal ammoniac. |
| Iron (black) | Sal ammoniac. |
| Iron (galvanized) | Muriatic acid. |
| Iron (tin coated) | Zinc chloride or rosin. |
| Inconel | Strong zinc chloride. |
| Lead | Tallow, rosin or zinc chloride. |
| Monel | Zinc chloride. |
| Nickel | Zinc chloride. |
| Pewter | Turpentine. |
| Stainless steel | Zinc chloride. |
| Steel (plain) | Sal ammoniac. |
| Steel (galvanized) | Muriatic acid. |
| Steel (tin-coated) | Zinc chloride or rosin. |
| Zinc | Muriatic acid. |

### Soldering Glass

Here's how it's done: slightly abrade the glass surface with a grinding wheel. Then fill the wheel with solder by holding a bar of solder against it as it turns. Carefully go over the abraded surface of the glass with the solder-loaded grinder. Use this solder deposit to join the glass with the metal part. You'll find the resulting joint will be nearly as strong as a metal-to-metal joint. Why not give it a try?

Modern soldering offers another advantage. It's the one process that can be applied in many different ways—with different equipment.

Why not see where you can put soldering to work? It's a process that can save you time and dollars over the years.

## UPSTAIRS WITH INERT-GAS METAL-ARC WELDING

The welding technique used and described in the above mentioned article, which was published on pages 1197 and 1198 of the December 1957 issue of *The Welding Journal*, was developed by the J. D. Christian Engineers and Holo-Flight International Incorporated of San Francisco. The machine that is used to carry out this technique is patented and is the property of Western Precipitation Corporation of Los Angeles.

# WORN SUGAR-CANE DRIVE ROLLS RECLAIMED BY GAS-SHIELDED WELDING

BY C. B. ROBINSON AND W. R. LAWRENCE

Since drive rolls used in Hawaiian sugar-cane crusher mills represent a sizable investment, many skilled engineers had sought for a way to reclaim them with a method that was both metallurgically and economically sound.

Specialists have come up with successful welding procedures for building up these valuable shafts and increasing their service life—using the gas-shielded metal-arc process.

The buildup had to withstand rugged operating conditions. The drive rolls operate in a floating bearing under constant pressure in the presence of sugar acids, water and cane contaminated with soil and lava rock

C. B. **Robinson** is associated with Process Development, Air Reduction Pacific Co., and **W. R. Lawrence** is associated with the Sales Department, Gaspro, Ltd., Hawaii.

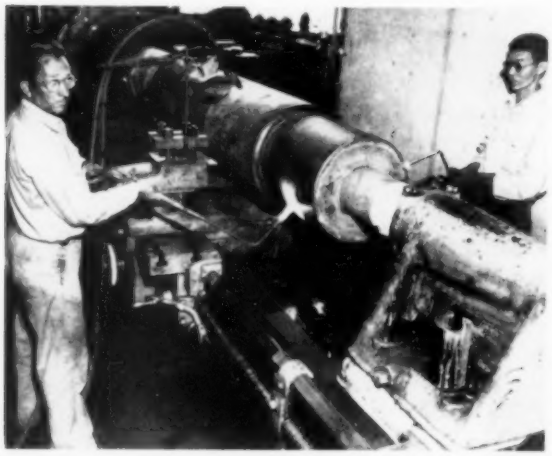

Fig. 1 Preheating worn drive roll with oxyacetylene torches to 600° F prior to buildup

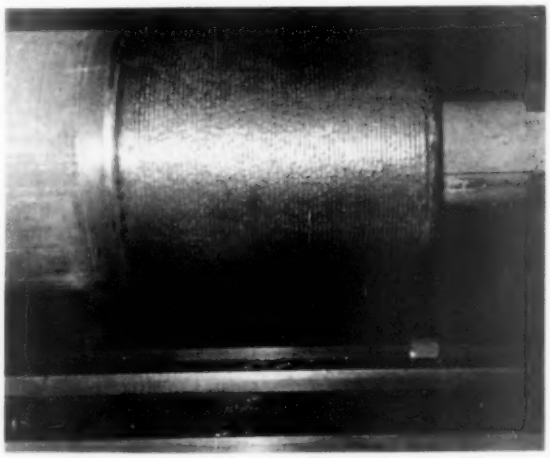

Fig. 3 Finished buildup of 17½-in. diam drive roll. Rolls must stand constant pressure of 2000 psi

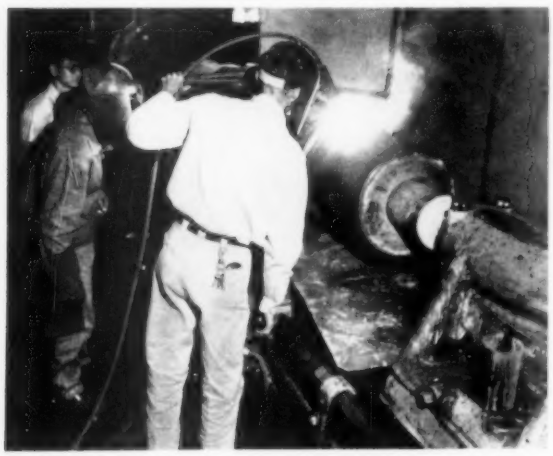

Fig. 2 Gas-shielded metal-arc process performs buildup with Type 316, 19-9 5/64-in. stainless-steel wire

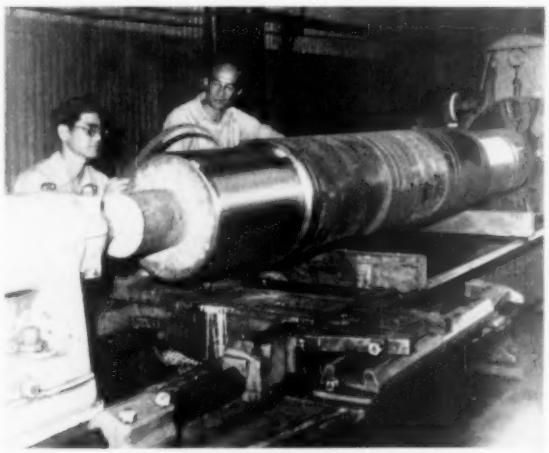

Fig. 4 Final machining to exact diameter completes operation. Here tolerances are checked

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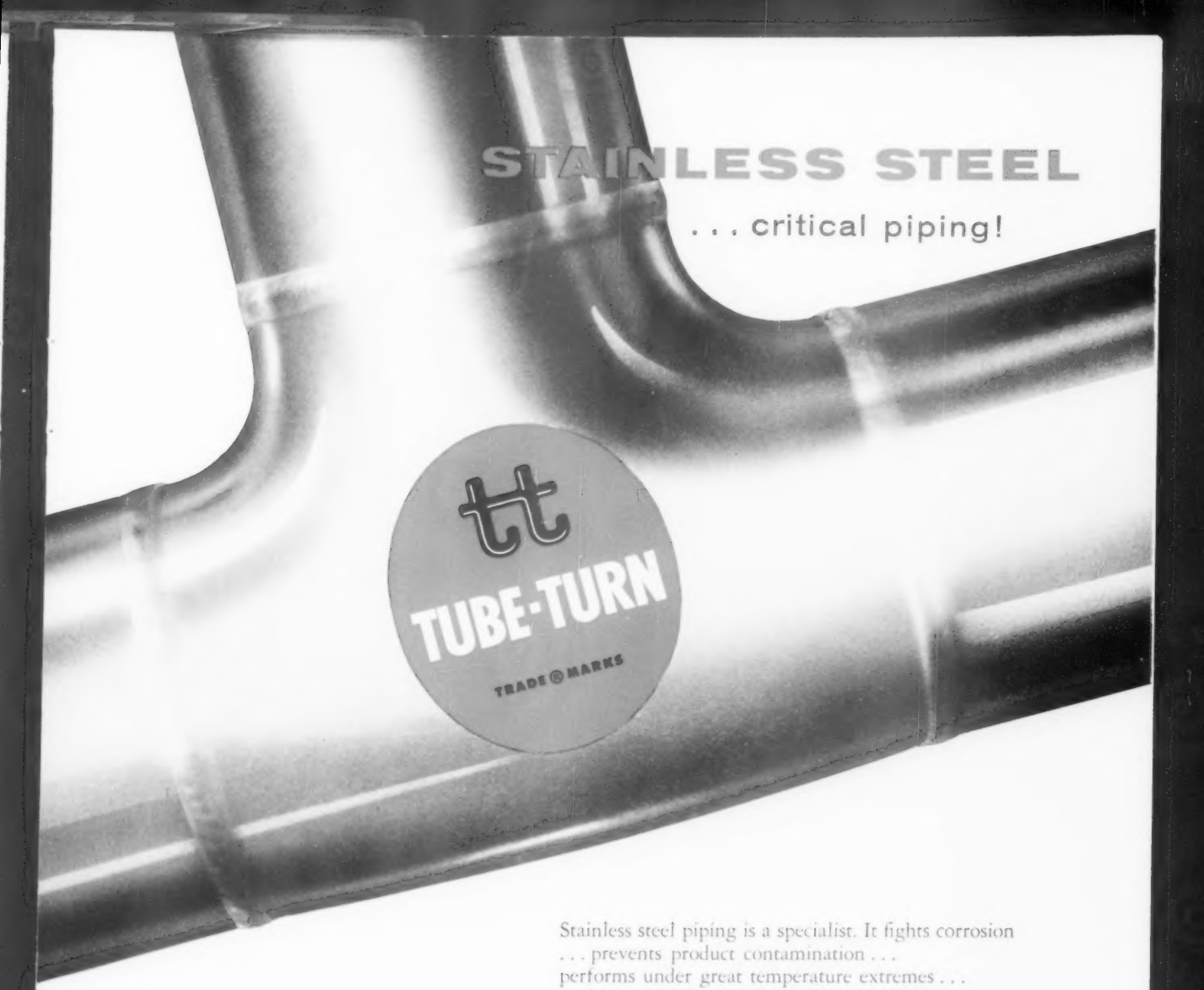


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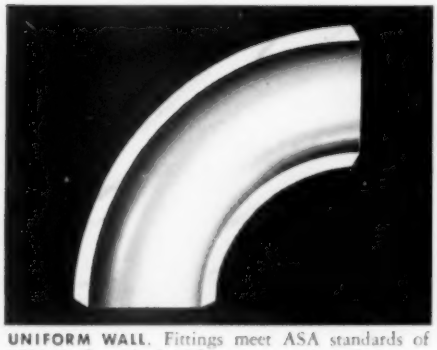

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particles. Therefore, Type 316, 19-9, $\frac{1}{16}$-in. stainless-steel wire was selected to offset pit corrosion and provide toughness. It also provided good "work hardening" characteristics.

A manual welding gun using argon and 2% $O_2$ for the shielding gas was chosen to perform the buildup. It was powered by a 400-amp d-c welding machine which could maintain steady power over sustained welding periods, since each pass took $1\frac{1}{2}$ to 5 hr to complete on these $17\frac{1}{2}$-in. diam rolls. The procedure was briefly as follows: the roll was first prepared by machining to remove all fatigued surface metal and contaminations. It was then mounted on a lathe capable of handling the drive roll at a surface speed of 12 to 15 ipm. The roll was next preheated to 600° F with oxyacetylene heating torches (Fig. 1). Surface speed was adjusted to 15 ipm and three threads per inch. The manual welding gun was positioned to make the weld deposit slightly on the up-hill side to insure a wide cladding bead with a minimum of diluted base metal (Fig. 2). The wire feed was set at 200 ipm.

Constant check was maintained through the operation to assure that the heat was held at 600° F. The number of passes necessary was dependent on the condition of the drive roll. For example, one roll was worn down to where it required four passes, another needed only two.

When the cladding was complete (Fig. 3) the entire area was postheated to 600° F and held at that temperature for a minimum of 2 hr to eliminate any brittleness. The newly clad drive roll was then wrapped in asbestos and allowed to cool slowly.

Final machining to exact diameter (Fig. 4) completed the operation, and the reclaimed drive roll was ready again to meet with even better service life than before the heavy demands of the sugar grinding season.

# SCHOOLHOUSE ON STILTS

Dusk lends a striking photographic touch to the new Phillis Wheatley Elementary School in Orleans Parish, New Orleans, (Fig. 1). Confined to one city block, the all-welded structure is erected 10 ft off the ground on two rows of ten concrete foundation piers each, plus exposed supporting columns under the end trusses. This permits a large, open center play court, 220 x 34 ft, as well as a virtually unobstructed area beneath the classrooms, each of which accommodates 35 pupils.

Over-all dimensions are 312 x 104 ft, with 12 cantilevered rectangular trusses forming 27-ft, 6-in. bays and tieing into floor and roof framing. Classroom wings, thus, overhang the supporting piers by 35 ft on either side, calling for some unique structural analysis and design work in evolution of the truss form. They are partially shop welded, then field spliced by groove butt and fillet welding. Steel sections are principally wide-flange beams, with bulb-tee roof purlins and a wide variety of reinforcing and trim elements, including channels, plates and I-beams, totaling in all better than 300 tons.

Welded design contributed to clean, smooth lines, important by virtue of the permanently exposed nature of the framing. It also permitted a 15% saving in steel tonnage over riveted design. Originator of the construction idea was B. M. Dornblatt & Associates, Inc.; architect, Charles R. Colbert; contractor, Keller Construction Co., all of New Orleans.

Based on a story by the Lincoln Electric Co., Cleveland, Ohio.

Fig. 1 Phillis Wheatley Elementary School in Orleans Parish, New Orleans, La.

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# Society News

## Nippes to Present Adams Lecture at 1958 AWS Spring Meeting

The traditional Adams Lecture at the 1958 AWS National Spring Meeting will be delivered by Ernest F. Nippes and will follow the opening-day ceremonies at the Hotel Statler in St. Louis on Monday, April 14th. Twenty-one technical sessions, 4 of which will be sponsored by the ASME Metals Engineering Division, will be included in the 1958 meeting. An educational lecture series will also be featured.

The Adams Lecture was created in 1943 to honor the founder and first president of the SOCIETY, Dr. Comfort Avery Adams. This distinction is conferred annually upon an outstanding scientist or engineer, and his lecture presents some new or distinctive development in the field of welding. Dr. Nippes' background certainly reflects this latest honor bestowed upon him. He is currently Professor of Metallurgical Engineering and Director of Welding Research at Rensselaer Polytechnic Institute in Troy, N. Y. The author of more than 40 articles on welding, Dr. Nippes has served as chairman of the Northern New York Section and is a member of several technical committees of the Welding Research Council.

The title of this year's Lecture is "The Weld Heat-Affected Zone." As is well known, pioneering studies of the effect of weld thermal cycles on the microstructure and mechanical behavior of the base metal in the heat-affected zones have constituted a major field of interest in the Welding Laboratory at Rensselaer Polytechnic Institute for the past decade.

Included in the AWS-sponsored technical program will be two sessions each on resistance welding, brazing and gas-shielded welding. There will be 3 sessions on steel weldability and research, while single sessions will be held on titanium; aluminum and magnesium; uranium, titanium and high-nickel alloys; submerged-arc welding; application, equipment and inspection; welding arcs and heat flow; welded structures; and designing for welding.

The ASME's sessions will deal with strength of welds; mating of structural properties with design; design and material for low-temperature application; and casting weldments.

The educational lecture series will feature a two-part subject, "Engineering Behavior of Welded Structures," to be given by Professor Earl R. Parker of the University of California at Berkeley's Division of Mineral Technology.

The Sixth Annual Welding Show will be held on April 15–17 at the Kiel Auditorium. An anticipated sellout of display area will make this show the largest ever sponsored by the AMERICAN WELDING SOCIETY, surpassing last year's record-breaking exhibition at Philadelphia's Convention Hall.

**1958 ADAMS LECTURER**

Ernest F. Nippes will speak on "The Weld Heat-Affected Zone" at the 1958 AWS National Spring Meeting in St. Louis on April 14th

**PANORAMIC VIEW OF ST. LOUIS AND ITS HOTELS**

Concentrated in an area of about a square mile—within walking distance of the Auditorium—are most of the city's leading hotels. A few are shown here. (A) Kiel Auditorium, (1) Statler, (2) Lennox, (3) Sheraton-Jefferson, (4) Mayfair, (5) DeSoto and (6) Mark Twain. The Hotel Statler will be the official AWS headquarters for the 1958 National Spring Meeting

# THINGS YOU SHOULD KNOW

(That Happened in December)

## An Expression of Appreciation

• I am writing these notes at home during New Years Day 1958. You will be reading them as part of the February issue of THE WELDING JOURNAL. Last June I agreed to accept responsibility for guiding and coordinating the activities of your headquarters staff. Public announcements of this change have appeared in many publications. Several hundred members and friends of the AMERICAN WELDING SOCIETY have taken the time to telephone, telegraph, write or verbally express to me their good wishes and congratulations, and to indicate their appreciation of the varied activities of the SOCIETY and their faith in its future. To all of these and to the many others who have just sent holiday greetings I wish to express my sincere personal thanks. I regret that I cannot personally contact each of you.

•

• Thanks to the effective leadership of your National Officers—President Sander, First Vice-President Hoglund, Second Vice-President MacGuffie, Treasurer Rockefeller and many others—and the loyal performance of your staff members, SOCIETY activities are being broadened by each department. Membership has not shown a significant drop following the recent changes in by-laws and the slackening of industrial activity. Operations during the first seven months of this fiscal year result in a financial picture somewhat better than that predicted in the balanced budget adopted by your Board of Directors last June. The number of contracts already completed for space at the Welding Exposition to be held in Kiel Auditorium in Saint Louis next April 15-17, indicates a complete sale of all space and a larger Exposition than the record one held in Philadelphia last April. The program for the annual meeting to be held April 14-18 in Saint Louis' Hotel Statler includes an unusually diversified list of outstanding papers providing new information for AWS members. Every Section meeting notice should include information about the 1958 Annual Meeting and Welding Exposition, urging members not to miss this exceptional opportunity of helping themselves and their companies.

• Leon Bibber, an active AWS member for many years, visited headquarters on December 9th to discuss technical activities with your Secretary and other staff members. Leon, who will soon retire from his position with the U. S. Steel Corp., is building a boat (on which he now lives) on the river at Pittsburgh. Following his retirement he will travel down the Ohio and Mississippi and then move his home at will along the Atlantic coast and elsewhere.

• On December 10th the New York Section held a successful meeting with A. L. Seiden as chairman and S. Sheer presenting an excellent discussion of the use of welding in building construction. Attendance was held down by bad weather and a partial subway strike, as Mr. Sheer explained how redesign for welding of a large bank building had speeded construction and saved the customer a significant percentage of the cost.

• The following day Second Vice-President MacGuffie visited headquarters to discuss publicity and public relations problems. During these same two days, the Pressure Vessel Research Committee held its quarterly meetings.

First Vice-President Hoglund, who is also chairman of your Technical Council, visited headquarters on December 17th to confer with Technical Secretary Fenton, Handbook Editor Phillips and your Secretary concerning the advisability of establishing technical groups and including chapters in the Handbook concerning spraying of ceramics on metals, joining metals to non-metals, welding of plastics and similar closely allied procedures.

• On December 20th Assistant Treasurer Mooney and your Secretary conferred with Treasurer Rockefeller in his office prior to a visit to the bank vault where securities held in the SOCIETY Reserve Funds are stored. Mr. Rockefeller has recovered from a serious operation and is now spending a major part of each business day in his office. He has been especially helpful in organizing the SOCIETY budget and in guiding financial policies.

• December 30th was devoted to a conference with Ed Grief who is in charge of publicity for the Annual Meeting and Welding Exposition for which Bob Kenworthy is manager.

• C. E. Jackson has been selected to give the 1959 Adams Lecture in Chicago. Clarence is chairman of your Educational Activities Committee and is planning an important conference to be held at Saint Louis during the Annual Meeting. Each Section should plan for their education representative to attend if at all possible.

• During January your Secretary will join President Sander for a series of meetings with West Coast and Rocky Mountain Sections.

*Fred L. Plummer*

## AWS DIRECTORS-AT-LARGE

| Term Expires | 1958 | 1959 | 1960 |
|---|---|---|---|
| | F. H. Dill | J. H. Blankenbuehler | J. F. Deffenbaugh |
| | E. D. Peters | G. E. Linnert | A. E. Pearson |
| | J. L. Wilson | P. G. Parks | C. M. Styer |
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# EAC DOINGS

## Welding Education Enters New Field

On December 19th a meeting was held at headquarters, to determine how the AMERICAN WELDING SOCIETY could help the Boy Scouts of America. At the meeting were Keith K. Peaslee, National Director, Boy Scouting Service; Fred L. Plummer, National Secretary, AWS; Clarence E. Jackson, Chairman; and Arthur L. Phillips, Secretary, EAC.

The Boy Scouts' need for technical assistance was revealed originally by a letter from a Nebraska scoutmaster. In the letter he said, "I have been a Boy Scout leader for a number of years and, because I am a welder, I have been trying to get requirements together for a merit badge in welding. . . . If there is any possible way you could work with the National Boy Scout Office, . . I think you would be doing a great service."

The Boy Scouts National Council was approached and found to be very receptive to the idea. Mr. Peaslee wrote us a letter explaining the thinking behind the development of merit badges. He also sent us a 68-page booklet, "Metalwork," in the Merit Badge series, which contained the information and tests required for the merit badge in metalwork.

The thinking behind these merit badges would appear to be in favor of the avoidance of narrow specialization and the adoption of a broad field of interest. In the field of metalwork the youngster is exposed to many metal-working techniques. He is introduced to many processes and is encouraged to pursue the subject which interests him most. In the booklet the following subjects are discussed: metals, mining and refining, tools and processes, bench-work projects, tin can craft, forge and foundry and, finally, opportunities in the metal-working industries.

The booklet was examined with great interest. It was an excellent little book, well written, adequately illustrated and very informative. It was in urgent need, however, of revision. The joining methods mentioned were riveting—one paragraph; soldering—one and a quarter pages; forging—six and a half pages.

A letter was sent to Keith Peaslee pointing out the broad horizontal nature of welding and related metal-joining techniques. It mentioned the fact that there is no industry where metal is used which does not rely upon some form of metal joining and suggested that a merit badge in welding could be developed. This would show the boys, at an early age, both the importance and the wide range of metal-joining techniques.

When the meeting took place in December, the exchange of views and information was more than valuable. It was learned that great emphasis was placed on the man-boy contact between the scout and his grown-up counselor and how valuable this relationship had proved. The National Boy Scout Director told of what other engineering groups were doing, how the best brains in the country were helping to plan these activities.

Mention was made of a unique undertaking in Milwaukee which has been organized with the assistance of the local electric company, the Electrical Contractors' Association and the Council's merit badge counselors.

A one-day program has been developed to enable scouts and explorers to earn the "electricity" merit badge. The clinic is held at the Public Service Building. The youngsters receive instruction and testing in all eleven of the merit badge requirements and each boy completing the program successfully receives credit for the merit badge.

This clinic is the culminating point of the work for the merit badge. Much of the material must be prepared in advance, and it is here that the boys meet with their counselors and preserve the valuable man-boy contact.

## AWS TO SHARE NEW HEADQUARTERS FOR ENGINEERING SOCIETIES

**At their meeting of Nov. 7, 1957, the Board of Directors of the AMERICAN WELDING SOCIETY approved the recommendation of the Headquarters Housing Committee that the SOCIETY accept the invitation to establish its headquarters in the new $10,000,000 United Engineering Center in New York City. This Center, including a modern 20-story tower adjacent to the United Nations Building between 47th and 48th Streets, will provide air-conditioned office space together with dining facilities, complete library, display rooms, meeting rooms and many coordinated central facilities. It will be occupied by more than twenty of the major national technical and engineering groups**

The Milwaukee Police Department and the American Red Cross sponsor a similar clinic for the merit badge in First Aid. A corps of police officers and Red Cross instructors are on hand to provide the training for small groups of the boys.

The American Welding Society, through its educational committees, has been requested to examine the merit badge booklet, "Metalwork," with a view to a revision which will be more realistic in its approach to metal joining and more in keeping with present-day requirements. The AWS has accepted the assignment, glad to have the opportunity of making such a contribution to the Boy Scouts of America.

Through the medium of the 81 sections of AWS it may be possible to provide a nationwide counseling service to help the eight thousand or more youngsters who earn these badges each year. This would help to solve one of education's most pressing problems—how to introduce youth to welding engineering at an age sufficiently young to enable them to study the subjects they will need in their future careers.

## Eutectic Enrolls as Supporting Member

The Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing, N. Y., has enrolled as a Supporting Company Member with an effective commencement date of July 1, 1957.

Including new members or present members of AWS on an individual basis, Eutectic now comprises a total of approximately 70 memberships.

## Stoody Company New Sustaining Member

The Stoody Co., Whittier, Calif., has been added to the list of firms holding Sustaining Memberships in the American Welding Society.

Established in 1921, Stoody Co. provides a complete line of hard-surfacing alloys for manual, semiautomatic and automatic applications. The company was the first to produce fabricated tubular rods which contain alloys; the first to offer such tubular wires in coils for full automatic and semiautomatic welding machines. Other regular production items include nonferrous alloy wear-resistant castings and blast cleaning nozzles using tungsten carbide liners. Trade names include Stoodite, Tube Borium and Borod.

Albert J. Zvanut, metallurgist, has been appointed Sustaining Member representative.

# Resolution

### Isaac Harter

It cannot be said that Isaac Harter left us too early in life; he was born in January 1880. Seventy-seven years is a long span of life. But his death was early for a man who at his age was still giving so much to his profession, to society, to his friends, to ideas, and to the problems of humanity. In this lies the tragedy of his loss, the deep bereavement of his friends.

It does not seem important where he was born for he was a man that belonged to the world. He first saw the light of life in Mansfield, Ohio. An eastern school, in Philadelphia, then St. Paul's, and the University of Pennsylvania first shaped the lovable character of the man, his searching mind, his respect for opposing views, great variety of interests, intuitive kindness, broad, sensitive and understanding outlook on life and, foremost among them, good will toward all.

It is hardly believable that with all his capacity for diversified interests, he found time and concentration for distinguished achievements in his chosen profession. As an engineer he will long be remembered as an outstanding builder; builder of ideas which have become professional achievements and brought renown to him and his affiliations.

Starting as a young man with the Babcock & Wilcox Co. in 1907, he consistently and steadily had managerial responsibility shifted to his shoulders. It must never be forgotten—for this is why his memory is so cherished—that he never, never let his position of responsibility overshadow him as an engineer and as an elder advisor—kind, understanding and sensitive. Even when performing the exacting duties of vice president and director during the period of 1921-47, or as chairman of the board of the Babcock & Wilcox Tube Co. since 1947, he also was the active force behind many technological advances.

Technical Societies—the fraternities of dedicated men—found in him an earnest disciple. He was forever willing to contribute to the labors of the society to which he chose to belong; this, too, was characteristic of him. Whether at the desk in his private office or at the council tables at the headquarters of the Society of Mechanical Engineers, the American Welding Society, the British Institute of Metals, or many others, he gave fully of his immense abilities. The new and the unconquered attracted, fascinated and challenged him; until the very last day he was active in matters of atomic energy.

He wrote and read, and his friends—and he had no others around him or away from him but friends—benefited from his interests. Just a few days before he took his leave to sadden us until we, too, depart, he mailed to a few of us a Chinese poem that well fitted his views on life.

As is with so many that live with a spark of greatness in them, he loved and cherished the creations of God; his acceptance of the principles of Christian behavior made him a believing Christian, and such he remained unto his death.

To sum up, Isaac Harter was a gentleman and a scholar of the highest order. He was a great man, a loyal friend, and an inspiring stimulus to all those who had the good fortune to know him well.

> Resolved, That this appreciation of Isaac Harter, the man of honor, the disciple of decency, the peer amongst great of spirit, the citizen of the free world, the builder of machinery and men, be entered in the records of the American Welding Society, and be it further resolved that a copy of this appreciation be addressed to Mrs. Harter as our expression of our common loss and our share in her sorrow.

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# Institute on Problems Encountered in the Welding of Alloys

**The University of Wisconsin**
**Madison, Wisconsin**

Feb. 12–14, 1958

Sponsored by the University of Wisconsin Extension Division in cooperation with the College of Engineering and the AWS Madison Section

*Welding Processes for Joining Stainless Steels*

WEDNESDAY, FEBRUARY 12

9:00–10:15 A.M. Manual Welding—Inert Gas
Metal-Arc Welding of Stainless Steels
Representative of Linde Co., New York

10:30–11:45 A.M. Automatic Welding of Stainless Steels
Representative of Lincoln Electric Co., Cleveland, Ohio

1:30–2:45 P.M. Resistance Welding of Stainless Steels
Representative of Sciaky Bros., Inc., Chicago, Ill.

3:00–4:15 P.M. Inspection of Welds—Destructive and Nondestructive Testing
H. B. Norris, Supt. of Nondestructive Testing, Allis-Chalmers, Milwaukee, Wis.

*Welding Processes for Joining Aluminum Alloys*

THURSDAY, FEBRUARY 13

9:00–10:15 A.M. Manual Arc Welding of Aluminum Alloys
Howard Adkins, Kaiser Aluminum & Chemical Sales, Inc., Chicago, Ill.

10:30–11:45 A.M. Automatic Welding of Aluminum Alloys
C. J. Sullivan, Manager, Process Development Section, Air Reduction Sales Co., New York

1:30–2:45 P.M. Resistance Welding of Aluminum Alloys
J. F. Deffenbaugh, Chief Electrical Eng., The Federal Machine & Welder Co., Warren, Ohio

3:00–4:15 P.M. Welding Dissimilar Alloys
Representative of International Nickel Co., New York

6:30 P.M. Dinner Meeting
Eagles Club, Madison, Wis.
Modern Applications of Inert-Gas Shielded Tungsten-Arc Welding
Harry A. Huff, Air Reduction Sales Co., New York

FRIDAY, FEBRUARY 14

9:00–10:15 A.M. Selection of Electrodes and Filler Rod for Special Alloys
Representative of A. O. Smith Corp., Milwaukee, Wis.

10:30–11:45 A.M. Welding of Special Alloy Piping, Pressure Vessels and Tubing
Representative of Inland Steel Co., Chicago, Ill.

1:30–3:00 P.M. Panel Discussion—"Problems Encountered in Welding Special Alloys" (Panel composed of speakers from previous days)
Moderator—T. B. Jefferson, Editor
The Welding Engineer

3:15 P.M. Award Certificates

# Section News and Events

as reported to Catherine O'Leary

## CHRISTMAS PARTY

Albuquerque, N. Mex.—The *Albuquerque* Section Christmas Party on Dec. 14, 1957 was the scene of the presentation of a fine prize (a turkey) to the member who brought the most new members into the Section. Eldon Glover received the prize for bringing in seven new members.

The Christmas party was attended by sixty-three members and guests who enjoyed the fine turkey dinner, a short movie and the dancing that followed.

## HOLD CHRISTMAS PARTY

At the December 14th Christmas party held by the Albuquerque Section, Eldon Glover was given a turkey as a prize for bringing in most new members. (*Left to right*) are J. J. Flowers, Wm. O'Brien, Mrs. Glover and Mr. Glover

## DISTRICT NO. 5 EXECUTIVE COMMITTEE MEETS IN TROY

A meeting of the District No. 5 Executive Committee was recently held at the Hobart Brothers Co. office in Troy, Ohio. Attendees shown above are, left to right, Solon McDonald, Chairman of the North Central Ohio Section; Dick Stratton, Vice-Chairman, Dayton Section; Bill Brown, Chairman, Cincinnati Section; John Blankenbuehler, Director-at-Large; William H. Hobart, Jr., host to the meeting; Harold E. Schultz, District Director; Bill Mayor, Chairman, Cleveland Section; Tom Dempsey, Vice-Chairman, Cleveland Section; Frank Gue, Chairman, Dayton Section; and J. J. Vagi, Chairman, Columbus Section

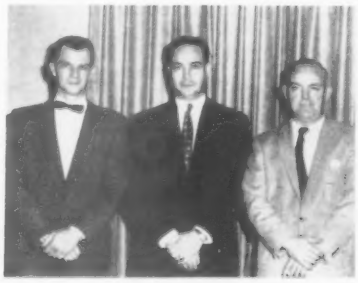
## WELDING T-1 STEEL

Birmingham, Ala.—The Dec. 3, 1957 meeting of the *Birmingham* Section was a joint meeting with the American Society for Metals held at the Redmont Hotel.

Perry C. Arnold (M'43), chief field welding engineer, Chicago Bridge & Iron Co., Chicago, was the speaker. Due to the interest in this new field, his subject, "Problems Associated with the Welding of T-1 Material," was a timely choice and the meeting was attended by 110 members and guests of both societies. Mr. Arnold presented

## PANEL DISCUSSES RESISTANCE WELDING AT CLEVELAND MEETING

"Dutch" Bodenheim (*left*) acted as moderator at the Dec. 11, 1957 meeting of the Cleveland Section. Two of the panelists, J. C. Kittle (*center*) and R. Gibbons (*right*) are shown with him above



Additional members of the panel that discussed resistance welding were R. MacDonald (*left*) and D. Hanlon (*right*). Mr. Gibbons is at center

Mr. Kittle (*center*) is pictured above with the two remaining members of the panel, C. F. Moulton (*left*) and V. O. Baker (*right*)

his talk in an interesting and informative manner with pictorial and technical slides. His talk was well received.

## WELDING METALS

**Raleigh, N. C.**—The regular monthly meeting of the *Carolina* Section was held in the S & W Cafeteria, on Nov. 25, 1957.

Members were served their meals cafeteria style and then adjourned to a room reserved for the meeting where an interesting discussion developed, and many problems were solved.

Speaker was William Austin, professor and head of Mineral Industries at North Carolina State College. Dr. Austin spoke on "Metals, What You Should Know About Them When Welding." His talk was very interteresting and ran longer than anticipated. However, no one left until the talk was over, although many members had to travel more than a hundred miles to attend this meeting.

## RESISTANCE WELDING

**Cleveland, Ohio**—The December meeting of the *Cleveland* Section was devoted to resistance welding. The large group that made its way through an early winter snowstorm on Dec. 11, 1957 to the Hotel Manger attested to the interest in the Cleveland area in this subject.

The technical session was ably conducted by "Dutch" Bodenheim of Federal Machine and Welder Co. He skillfully moderated a panel of experts, who, indeed, appeared very expert in answering the many questions fired from the floor. The number and quality of the questions indicate that this type of program is a successful technique for developing an interesting program on what can be a highly technical and difficult subject. A film on resistance welding, produced by the Resistance Welding Manufacturers Association, stimulated the meeting.

Serving on the panel were V. O. Baker of P. R. Mallory Co.; J. C. Kittle, Whirlpool Corp., Clyde Division; Robert MacDonald, Precision Welder Co.; Robert Gibbons, Chevrolet-Cleveland; C. F. Moulton, National Welder Co.; and Dan Hanlon, Eaton Stamping Division.

The technical session was preceded by a "coffee talk," given by Harrison Dillard. Mr. Dillard, now on the public relations staff of the Cleveland Indians baseball club, talked about his Olympic Games experiences and discussed the 1958 prospects of the ball team.

# SECTION MEETING CALENDAR

### MARCH 3

LEHIGH VALLEY Section. Joint meeting with ASCE. Dinner 6:30 P.M. Meeting 8 P.M. Walp's Restaurant, Allentown, Pa. "Welded Girders," Omer Blodgett, Lincoln Electric Co.

### MARCH 7

NORTH CENTRAL OHIO Section. Mansfield. Plant visitation. Fisher Body.

PHILADELPHIA Section. Engineers Club. 7:45 P.M. Panel discussion "Why Iron-Powder Electrodes."

### MARCH 10

NORTHWEST Section. Minneapolis, Minn. Elks Club. Happy half hour 6:00 to 6:30 P.M. Dinner 6:30 P.M. "Alloy Fluxes and Hard Surfacing," Robert Wilson, Lincoln Electric Co.

### MARCH 11

DAYTON Section. Dayton Ohio. "Kald Weld Proceis and Equipment," H. Wellar, Utica Drop Forge & Tool Corp.

NEW YORK Section. Victor's Restaurant, 1 E. 35 St., N.Y.C. Get-together 5:30 P.M. Dinner 6:00 P.M. Program 7:00 P.M. "Submerged Arc," A. G. Hogaboom, Bethlehem Steel Co., Shipbuilding Division.

SAGINAW VALLEY Section. Saginaw, Mich. Joint meeting with ASM. "The Metallurgy of Ferrous Welding," W. D. Doty, U. S. Steel.

WESTERN MASSACHUSETTS Section. Silhouette Restaurant, Thompsonville, Conn. Dinner 6:30 P.M. Meeting 7:30 P.M. "Welding of Stainless Steel," H. F. Reid, The McKay Co.

### MARCH 12

CLEVELAND Section. Manger Ho el, Cleveland, Ohio. Social hour 6:00 P.M. Dinner 6:30 P.M. Panel meeting 8:00 P.M. "Design for Automa ic Welding."

STARK CENTRAL Sec ion Virginian Restaurant, Alliance, Ohio. "Recent Advances in Aluminum Welding," P. B. Dickerson, Aluminum Company of America.

### MARCH 13

KANSAS CITY Section. "Welding of Clad Steel."

MADISON SECTION. Janesville, Wis. Panel Discussion, "Gases Used in Welding."

### MARCH 14

DETROIT Section. Engineering Society of Detroit. Dinner 6:15 P.M. Technical meeting 8:00 P.M. "Welding Metallurgy," D. C. Smith, Harnischfeger Corp.

### MARCH 17

PHILADELPHIA Section. Engineers Club. 8:00 P.M. "Applications of Automatic Welding Processes in the Nuclear-Power Field," William Apblett, Foster Wheeler Corp.

### MARCH 18

HARTFORD Section. Villa Maria Hotel Glastonbury, Conn. "Good and Bad Practices in Structural Steel Welding," T. B. Jefferson, Editor, The Welding Engineer.

NORTHWESTERN PENNSYLVANIA Section. Erie, Pa. Plant Visitation—Hammermill.

TOLEDO Section. Dinner 6:30 P.M. Meeting 8:00 P.M. Maumee River Yacht Club. Alloy Cutting Clinic.

### MARCH 19

PEORIA Section. 7:00 P.M. Plant tour, Commonwealth Edison plant, Pekin, Ill.

PITTSBURGH Section. 8:00 P.M. Auditorium of the Mellon Institute of Industrial Research (Oakland) Pittsburgh, Pa. "Welding Inspection Techniques," Stanley A. Brosky, Brosky X-Ray and Research Labs. Inc.

PROVIDENCE Section. Dinner meeting 6:15 P.M Johnson's Hummocks, Providence, R. I. "Why Welds Fail," H. Thielsch, Grinnell Co. Inc.

### MARCH 20

BRIDGEPORT Section. "Code Welding," E. C. Korten, Hartford Steam Boiler Ins. Co.

IOWA Section. Kirkwood Hotel, Des Moines, Iowa. Social half hour 6:30 P.M. Dinner 7:00 P.M. Program 8:00 P.M. "Structural Plate Welding," Perry Arnold, Chicago Bridge & Iron Co.

MICHIANA Section. South Bend, Ind.

### MARCH 21

MILWAUKEE Section. Ambassador Hotel. 6:30 P.M. "Requirements for Practical Applications of Resistance Welding," J. C. Wilson, Acro Welder Mfg. Co.

### MARCH 27

NIAGARA FRONTIER Section. LaSalle Yacht Club, Niagara Falls, N. Y. Dinner 6:45 P.M. Meeting 8:15 P.M. "Welding Metallurgy," G. E. Claussen, Linde Co.

### MARCH 28

INDIANA Section. Plant tour and dinner. Linde Products, Speedway, Ind. "Magnetic-Flux Welding."

*Editors' Note: Notices for May 1958 meetings must reach Journal office prior to March 1, so that they may be published in April Calendar. Give full information, concerning time, place, topic and speaker for each meeting.*

## LADIES NIGHT

**Denver, Colo.**—The *Colorado* Section held its Annual Ladies Night meeting on Dec. 11, 1957 at the Town House Restaurant in Denver. It was a dinner dance preceded by a cocktail hour. Good music was supplied by a local orchestra. Section Chairman Bob Scott and Program Chairman Johnny Mascarello worked very hard to make this affair click and their efforts succeeded. Everyone had a good time and the affair was a big success.

## AUTOMATIC HANDLING EQUIPMENT

**Dayton, Ohio**—A regular meeting of the *Dayton* Section was held on Dec. 10, 1957 at the Dayton Engineers Club.

The meeting, attended by forty-five members and guests, was opened with the showing of a color travel film entitled "Wings to Hawaii" which helped those in attendance forget the cold and the snow outside.

The principal speaker, Robert Moore, president of Moore Equipment Co., gave a highly interesting talk on "Automatic Handling Equipment." His talk covered some of the more unique special machines and hopper feeding devices built for various manufacturers.

Mr. Moore showed two color films, one covering various vibratory feeders and the other showing some ingenious types of placing heads.

At the close of the talk, Mr. Moore operated two demonstrator vibratory hopper feeders and showed samples of various types of parts which have been fed with vibratory hoppers.

## CHRISTMAS DINNER DANCE

**Holland Town, Wis.**—One-hundred and twenty-five members and their wives attended the annual Christmas Dinner Dance of the *Fox Valley* Section held on Dec. 7, 1957 at Van Abels Inn, Holland Town. A wonderful time was had by all.

## ROCKETS AND MISSILES

**Beaumont, Tex.**—The Sabine Division of the *Houston* Section met on December 5, 1957 at the Flying Chef Cafe, Jefferson County Airport. Speaker was Lawrence F. Megow (M'52), general manager, Hahn and Clay's Steel Fabricating Division, Houston. Mr. Megow spoke on "Rockets, Missiles, Satellites and You."

His talk covered the general principle on which a rocket works with a live demonstration on a small scale working model. He pointed out some of the many complicated problems, including those of welding unusual materials which must be overcome before space travel will become a common, every-day occurrence. He touched briefly on each of the interesting aspects of rocketry such as time factors involved, types and amounts of fuel necessary for rocket engines, new materials to withstand the tremendous heat caused by air friction, atmospheric conditions which are still unknown, gravitational pull of both the earth and other planets. Mr. Megow took us on an imaginary rocket trip to the moon pointing out many of the problems, both humorous and serious with which one would be confronted.

Mr. Megow has been very active in the organization and sponsorship of a group of senior high school students in Houston, Tex., called "Rocket Research and Development Society." He brought with him as a guest speaker the chief engineer of this society, Dennis Ashton of Houston, Tex.

Young Master Ashton gave a very interesting talk on the design, fabrication and actual firing of rockets by his society. His talk was illustrated with hand-drawn sketches on the blackboard. A movie showing his group setting up and firing homemade rockets was started but interrupted about midway of the film due to a breakdown of the projector.

## MAGNETIC-FLUX WELDING

**Kansas City, Mo.**—After a social hour beginning at 5:30 P.M., 36 members and guests enjoyed a steak dinner on Nov. 7, 1957, at the Golden Ox Restaurant, which has become the usual meeting place for the *Kansas City* Section this year.

The meeting began promptly at 7:30 with announcements and a short informal talk by Chairman Blaine Harrington. The principal speaker was then introduced in the person of Norman Davis (M'52), Linde Co., Newark, N. J., who spoke on the "Magnetic-Arc" welding process as developed by his company. Mr. Davis utilized a number of interesting slides in conjunction with his talk.

## ARC-WELDING FUNDAMENTALS

**Allentown, Pa.**—The *Lehigh Valley* Section met on Dec. 2, 1957 for dinner and meeting at Walps Restaurant in Allentown. Principal speaker at this meeting was Clarence E. Jackson (M'52), of Linde Co., Newark, N. J. In his talk on "Fundamentals of Arc Welding," Mr. Jackson covered the basic

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principles of arc welding and showed color slides to illustrate his remarks. His opening slide showed the family tree of arc welding processes.

The basic laws of electricity were explained to show welding circuits; also, the results were given when varying the voltage and the amperage to increase the arc gap and melting rate.

Mr. Jackson explained further how the heat is distributed when the various welding processes are used. In addition, he showed charts on the relationship of speed, current, etc. to penetration.

He stated that high-speed welding of aluminum is possible but, at the present time, mechanical equipment is not available.

In conclusion, Mr. Jackson noted that welding metallurgy will play an important part in the coming welding era.

## ANNUAL CHRISTMAS STAG OUTING

**Huntington Park, Calif.**—The *Los Angeles* Section *Aircraft and Rocketry Panel* and the *Long Beach* Section held their annual Christmas Stag Party at the Elks Lodge in Huntington Park on Thursday, Dec. 5, 1957. Approximately 210 members and guests were present to enjoy a night of pre-Christmas festivities.

## ARC WELDING IS THE SUBJECT

Clarence E. Jackson spoke on the fundamentals of arc welding at the December 2nd meeting of the Lehigh Valley Section. He is shown, at right, with Section Chairman R. A. Bartholomew

The festivities began at 6:30 P.M. with a social and cocktail hour. This was followed by a steak dinner and a short meeting. Among the guests introduced by Chairman Dave O'Connor was AWS President C. P. Sander, who never misses a meeting when he is in the Los Angeles Section area.

Vince Rossi at the piano and Nancy Cameron, accordionist, supplied the musical entertainment during the dinner and social hour.

Glamorous Gloria Manners, Mistress of Ceremonies, was in charge of the talent which was of outstanding quality and highly enjoyed by all. The Christmas Stag party put on by the Los Angeles Section has always been an affair to look forward to by the entire membership as a chance to deviate from the serious side of life.

## ARC-WELDING ELECTRODES

**Madison, Wis.**—Austin Hiller, of the Lukens Steel Co., Coatesville, Pa., was the guest speaker at the Dec. 12, 1957 meeting of the *Madison* Section, held at the Eagle's Club. Mr. Hiller's talk on "Arc Welding Electrodes—Their Performance, Comparison and Evaluation" was well prepared and delivered without the help of slides.

## Mahoning Valley to Sponsor Resistance-Welding Course

The *Mahoning Valley* Section, located in northeastern Ohio, is conducting a resistance-welding school during the month of March 1958. The course will consist of a series of six weekly sessions starting March 4th and covering all phases of resistance welding.

The first session will cover basic theory and equipment and will consist of a lecture and films explaining exactly what resistance welding is and how it is used. The second session will include demonstrations and actual welding by those in attendance, in the labs of Taylor-Winfield Corp. and Federal Machine and Welder Co., manufacturers of resistance welders, located in Warren, Ohio. Succeeding sessions will cover welder control, shop practice and mass production techniques. The final evening will feature a plant tour of a company using resistance welding in mass productions. Lectures will be held at the Ohio Edison Auditorium in Youngstown, Ohio.

Operators, maintenance men, foremen, engineers, students and all others interested are urged to attend. A nominal fee will be charged which will include a copy of a resistance-welding manual.

For further information and reservations, contact Mr. Forrest Johnson at American Welding & Mfg. Co., Warren, Ohio.


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## STAG PARTY HELD BY LOS ANGELES SECTION

Members enjoying refreshments and good fellowship during social hour at the Christmas Stag Party held by the Los Angeles Section on December 5th

Bob Waters and Leo West assist Nancy Cameron in a little harmony

Part of the large crowd that enjoyed the festivities, including a fine steak dinner

Delightful Gloria Manners, mistress of ceremonies, entertaining those present

Francis V. McGinly opens evening's program while Dave O'Connor, Dick Hayes, Howard Eubanks, John Wiley, President "Sandy" Sander and Chas. Concannon look on

President Sander "loses his head" in the guillotine set up by magician Dell O'Dell

## MAINTENANCE WELDING

**South Bend, Ind.**—Twenty-three members and guests of the *Michiana* Section braved this winter's worst weather on Dec. 12, 1957 to hear M. G. Balaban, owner of Balaban's Shop and Job Welding Co., South Bend, discuss maintenance welding.

Mr. Balaban likened the maintenance welder to a physician who must first diagnose the patient's trouble and then decide how to go about healing him. Like doctors in some instances, different welders will go about making repairs in different ways, often arriving at satisfactory results by a variety of methods.

He discussed some unusual problems encountered in his own shop and as a maintenance welder at the Studebaker Corp. A novel method of preheating a big ring gear by hanging eaves troughs on both sides and burning charcoal in them was mentioned.

While he didn't belittle the problems of the "fabricating" welder, Mr. Balaban figured that those of the maintenance man are complicated by on-the-site repairing of items which may mean working in a pit or high above the floor. Every job must be carefully studied so that it can be performed safely.

## STAINLESS STEEL

**Milwaukee, Wis.**—One hundred members and guests were present at the Dec. 14, 1957 meeting of the *Milwaukee* Section, held at the Ambassador Hotel. George Linnert [M'53], of Armco Steel Corp., gave an excellent talk on the difficulties encountered in "Welding of Stainless Steel." Mr. Linnert discussed the problems caused by intergranular corrosion, stress corrosion cracking and contamination due to contact of sulphur and zinc with the base material. His talk was accompanied with slides, and an interesting discussion period followed.

Preceding the technical meeting, Joe Taylor, Milwaukee Braves' assistant trainer, presented an interesting coffee talk on "The Inside Story of the World Series."

## STRUCTURAL WELDING

**New York, N. Y.**—The last meeting for 1957 of the *New York* Section was held on Dec. 10, 1957 at Victor's Restaurant, 1 E. 35th St., N.Y.C., where an excellent dinner was served prior to the meeting. This meeting was a huge success, especially in the face of the serious subway strike and the heavy storm.

The turnout was due to the double-barrelled feature of the principal speaker, Solomon Sheer [M'53], civil engineer and plan examiner in the New York City Department of Buildings.

Mr. Sheer gave a detailed report on the summer convention of the International Institute of Welding at Essen, Germany, captivating the audience with his description of the various countries he passed through, his visit to the Krupp Works in Essen and his explanation of how far advanced Europe is in welding matters.

Mr. Sheer devoted the second part of the technical session to the subject of "Welded Building Structures," using as his example the new Fifth Avenue Bank Building on 5th Avenue between 44th and 45th Sts. and giving blackboard diagrams of all types of welding sections.

The question-and-answer period was also very lively and interesting.

The Section was honored to have National Secretary Fred Plummer present.

## ALL-WELDED AIRPLANE

**Buffalo, N. Y.**—Sixty-eight persons attended the Dec. 5, 1957 meeting of the *Niagara Frontier* Section at the Continental Inn, Kenmore, N. Y. The Bell X-2 airplane was discussed by William L. Burch [M'52], welding engineer for Bell Aircraft Corp.

The X-2, world's highest-flying and fastest airplane, is especially interesting to welding men because it was the first all-welded airplane. It had no rivets and it used bolts only to attach the wings and to join the six fuselage compartments together. The wings were of spot-welded full hard Type 302 stainless steel.

Mr. Burch related how K-Monel was selected for the fuselage because only it had the requisite formability, strength at 700° F skin temperature, impact strength at liquid-oxygen temperature, and a heat treatment which would not warp the large sub-assemblies. For K-Monel only aging is needed and the Bell Metallurgy Group devised a low temperature-long time aging cycle which worked very well.

Joining of the K-Monel was by resistance, metallic-arc and inert-gas tungsten-arc welding. Base-metal cracking from both hot-shortness and contamination was a serious problem but techniques were devised to overcome this. After the talk, the Bell-made color movie, "Flight to the Future," was presented. This was filmed at Edwards Air Force Base and shows the preparation and testing culminating in a successful flight of the X-2. Mr. Burch concluded that the challenge to build an all-welded airplane had demanded much ingenuity and effort and had resulted in a


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| 213 | 475 | 1400 |
| 225 | 488 | 1450 |
| 238 | 500 | 1500 |
| 250 | 525 | 1550 |
| 263 | 550 | 1600 |
| 275 | 600 | 1650 |
| 288 | 650 | 1700 |
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structure that was exceptionally rigid and sturdy.

## QUIZ PROGRAM

**Findlay, Ohio**—Sixty-eight members and guests of the *North Central Ohio* Section were present on Dec. 6, 1957 at the Findlay Country Club for dinner and a Quiz Program with the following sections and members participating: *Cincinnati*, Stan Weiss (Capt.), Norm Woods-alternate, Bob McDonald, Bob Loosee, Geo. Hoppin; *Stark-Central*, Cliff Brainard (Capt.), J. P. Simon-alternate, Walt Edwards, E. W. Rowlands, Jr., Simon L. Fackler; *Cleveland*, F. Flocke (Capt.), A. G. Portz-alternate, J. E. Mallett, F. Bovie, W. Weber; *Toledo*, T. F. Ellis-Capt., M. J. Baughman, S. W. Snell, W. F. Schmidt.

Cincinnati won with a score of 850, followed by Stark Central with 605, Cleveland with 565 and Toledo with 530.

## ANNUAL TOUR

**Knoxville, Tenn.**—The *Northeast Tennessee* Section held its annual tour in the East Tennessee area on Monday evening, Dec. 2, 1957. The members were the guests of Dempster Brothers in Knoxville for dinner in the plant cafeteria and a complete tour of the plant facilities.

George Dempster, Ex-Mayor of Knoxville and top official of Dempster Brothers, was host to the AWS members and representatives from several welding-supply firms in the area.

During the two and one-half hour tour, the members observed the fabricating and welding operations conducted in the production of the huge Dempster Dumpsters as well as the fabrication of pressure vessels by the submerged - arc process. All plant equipment was demonstrated including models of the new Dempster Dumpmaster which is similar to an oversized Dumpster mounted on a truck chassis and equipped with a hydraulic refuse compaction device.

The seventy-six guests attending the tour also observed the huge presses manufactured by Dempsters that are used for compressing scrap metal into bales. These presses operate at pressures up to 600 tons and can easily compress a full-sized car into a package approximately the size of a bale of hay.

The tour was a huge success and a note of thanks is extended to Mr. Dempster and his fine staff.

## ALUMINUM WELDING

**Erie, Pa.**—The *Northwestern Pennsylvania* Section met on Nov. 19, 1957 for dinner and meeting at Larson's Restaurant in Erie.

Howard E. Adkins (M), welding specialist, Field Engineering Group, Kaiser Aluminum and Chemical Sales, Chicago, Ill., gave a brief history of aluminum welding, equipment needed for aluminum welding and properties of aluminum with regards to alloy selection.

## SPEAKS ON BRAZING

C. E. Rorick spoke on the brazing of stainless-steel honeycomb structures at the joint technical meeting of the Northeast Tennessee Section with the Oak Ridge Chapter of ASM on Nov. 20, 1957. Mr. Rorick is shown, at left, with Gerald M. Slaughter, technical activities chairman of the Section

## JOB-SHOP WELDING

**Peoria, Ill.**—James Bessler, of the Specialty Welding Co. of Peoria, spoke on the "Mechanics of Job-Shop Welding" at the Dec. 18, 1957 meeting of the *Peoria* Section held at the Mecca Supper Club. Mr. Bessler has had extensive experience in job-shop welding as a welder and as an instructor.

Among other things, he pointed out that a job-shop welder has to be a good businessman as well as a good mechanic; also, every job is a challenge because there are no two jobs

## PLANT VISITED BY NORTHEAST TENNESSEE SECTION

A portion of the Northeast Tennessee Section group inspecting Sheet Metal Department facilities while on tour of Dempster Brothers Plant in Knoxville, on Dec. 2, 1957

The Executive Committee of the Northeast Tennessee Section poses for this picture with George Dempster during plant tour. They are (*left to right*) Mr. Walden, sales manager for Dempster Brothers, T. D. Goodman, J. L. Irons, D. G. Scott, H. L. Felix, H. B. Harlan, D. W. Hackett, J. C. Thompson, T. C. Swindell, H. M. Payne, Mr. Dempster, Bert Searles and Chairman W. J. Leonard

## PANEL DISCUSSES WELDING INSPECTION PROBLEMS

Moderator Harry J. Irrgang and panelists Ralph D. Bradway, Robert G. Whaite and A. G. Ford, shown at the Philadelphia Section meeting on Dec. 6, 1957

alike. He said that a job-shop welder uses old, tried and proven methods.

He mentioned that the smaller jobs must be done with just as much care as the larger. He also explained some of the impossible jobs that they are called upon to do, as well as the humorous side of some other jobs.

## ANNUAL GET-TOGETHER

**Phila., Pa.**—Friday the 13th of December 1957 was not unlucky for the 16th annual get-together of the *Philadelphia* Section with the Society of Naval Architects and Marine Engineers. The SNAME was host this year to AWS. Approximately 120 participated in a well-rounded program which included a cocktail hour with musical entertainment, dinner, after-dinner talk and a technical program.

The "Rockets Red Glare" was the subject of an informal talk by E. Lavery of the Bell Telephone Co. General comments on the devastating possibilities of rockets combined with atomic warheads were followed by a description of specific features of the NIKE missile. He mentioned the parts played by the various divisions of his company and by U. S. Army Ordnance in the development and gradual improvement in this anti-aircraft guided missile. An action-packed scale model demonstration made a most effective ending to his talk.

The technical speaker was John L. Cahill [illegible], welding engineer of the New York Naval Shipyard. His talk on "Nondestructive Testing" was preceded by an excellent motion picture which showed, step-by-step, the

## PHILADELPHIA SECTION HOLDS JOINT MEETING WITH SNAME

The Philadelphia Section met with the Society of Naval Architects and Marine Engineers on December 13th. At speakers table *(left to right)* are John E. Cahill, technical speaker; S. F. Spencer, chairman, Philadelphia Section SNAME; E. Lavery, Bell Telephone Co., after-dinner speaker; Byron D. Gates, chairman AWS Philadelphia Section, and F. L. Pavlik, SNAME

At another table are *(left to right)* E. L. Teale, president, N. Y. Shipbuilding Corp.; S. S. Morse; Capt. J. M. Farrin, Commander, Philadelphia Naval Shipyard; Kent C. Thornton, J. J. Krieger, E. Goehringer, W. H. Wooding and C. E. Heil

Mr. Cahill discusses nondestructive testing in the construction of the super aircraft carrier, *U.S.S. Saratoga*

A moment of relaxation after dinner. Community singing led by A. M. Stefano. Seated (left to right) Mr. Pavlik, Frank Lapalucci and D. A. Worrell

Captain Frank Merkle, director, Naval Boiler and Turbine Laboratory, Philadelphia Naval Shipyard, and Mr. Pavlik discuss a point

construction of the super aircraft carrier *U.S.S. Forrestal* from the laying of the keel to the trial runs and commissioning.

The talk centered around the nondestructive testing methods used in checking the quality of welds in a vessel of the *Forrestal* class. With the use of numerous slides, Mr. Cahill showed how various familiar nondestructive testing methods are employed in a large industrial establishment. He described specific applications during the construction of one of the largest warships in the world—the *Saratoga*—at the New York Naval Shipyard in Brooklyn, N. Y. Applications of radiography, magnetic-particle inspection, dye-penetrant inspection and the use of ultrasonics were described in detail.

The immensity of the inspection task may be envisioned by the size of the *Saratoga* which dwarfs all other ships. Some idea may be had from the fact that the flight deck covers about four acres and could hold both the *Queen Mary* and the *Queen Elizabeth*, side-by-side, with plenty of space left over. Since it was practically all-welded construction, the inspection program for welds assumed the proportions of production. Also, the necessity for maintaining a very tight schedule of construction imposed additional challenges on the shipyard welding engineer who was responsible. Mr. Cahill presented a most informative talk and described some very unique and novel methods which were used in successfully solving inspection problems.

## BRAZE WELDING

**Providence, R. I.**—The *Providence* Section held its fourth successful meeting of the 1957–58 season on Dec. 18, 1957 at Johnson's Hummocks in Providence. This Section was organized only in June of this year, but it has a total of 127 members.

As usual, the members got together for a social hour before dinner. After dinner, Carl Rimmler, chairman of the Welding Problems Committee and superintendent of the Tower Iron Works in Providence, answered a welding problem submitted by one of the members. Upon completion, he brought it around for further discussion on other methods and possibilities. Mr. Rimmler's answer was very informative and very well received by the group.

The speaker for the evening was F. Emery Garriott [M'52], manager of the Weld Rod and Wire Department, coordinating research, production and sales of Ampco Metal, Inc., Milwaukee, Wis.

Mr. Garriott discussed new developments in brazing and braze welding with copper alloys and applications employing bronze electrodes and filler rods.

Mr. Garriott's presentation was of general interest since it dealt with electrodes and filler rods covered in the AWS-ASTM specifications. He discussed their usage in the joining of iron-base alloys, metals, dissimilar metals, overlay bronze welding for bearing wear and corrosion resistance applications.

He also covered the use of bronze wire with inert-gas consumable-electrode method for joining and overlay applications.

Mr. Garriott's talk, accompanied by slides, was very informative, educational and very well received by all.

Mr. Garriott is also an amateur magician and provided the group with an entertaining evening as well.

## WELDING OF ALUMINUM

**Rochester, N. Y.**—On Monday, Dec. 16, 1957 the *Rochester* Section held its monthly dinner meeting at the Liederkranz Club. About sixty members and guests enjoyed an excellent dinner, after which Gustav O. Hoglund [M'52], who is presently in charge of the Welding Division in the Alcoa Process Development Laboratories, delivered a very interesting talk on the "Metallurgical Aspects of Welding Aluminum."

With his talk, Mr. Hoglund showed some thirty slides which displayed the application, metallography and technical data associated with aluminum


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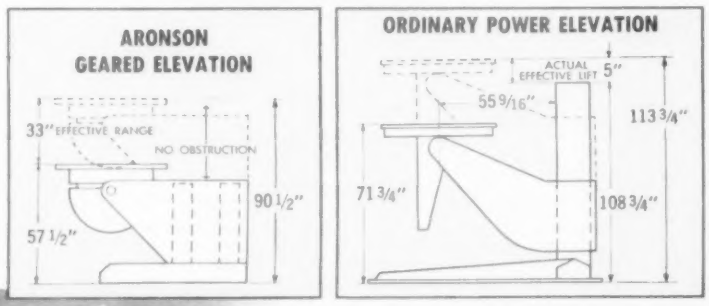


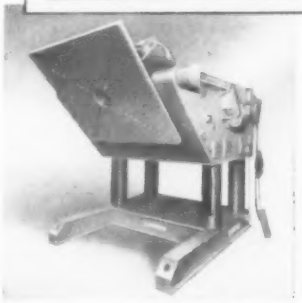

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weldments. Some of the tables showed the proper choice of welding electrodes, and shielding media were indicated for a wide range for aluminum alloys. Other tables illustrated the elevated temperature properties of aluminum-alloy weldments, while others showed fatigue and other mechanical properties of such joints.

In discussing welding techniques, Mr. Hoglund outlined the use of shielding gases employed with the inert-gas tungsten-arc process. He mentioned that, for commercial work, a 90% argon-helium mixture was quite satisfactory and produced good results. For a guarantee of the maximum protection from porosity, a 75% helium, 25% argon mixture was recommended. It was mentioned that helium used as a shielding gas gives higher arc voltages and deeper penetration than the same machine settings would give when employing argon as shielding media. He went on to say that the inert-gas-shielded tungsten-arc process was very satisfactory and raised few problems within its range of application.

Mr. Hoglund dwelled briefly on methods of electric arc cutting of aluminum alloys, mentioning the tungsten-arc process as being economical with such mixtures as hydrogen and argon. The metal-arc inert-gas-shielded process could be employed to cut aluminum alloys when used with a steel wire. He stressed that care must be used in any of the cutting practices on heat-treatable alloys, since there is also the possibility of edge cracking.

Mr. Hoglund concluded his talk by showing a film entitled "Welding Advantages with Aluminum," distributed by the Aluminum Company of America.

All the members present indicated that they felt Mr. Hoglund was one of the finest speakers the Section had heard in a long time.

## PAST-CHAIRMAN NIGHT

**Saginaw, Mich.**—One hundred and five members and guests of the *Saginaw Valley* Section met on Dec. 12, 1957 for dinner and meeting at the High Life Inn to honor the past chairmen.

The initial program consisted of a historical review of the Section's origin, accomplishments and progress, presented by Past-Chairman Robert Woollard. All past chairmen present were introduced and recognized for their contributions.

Since the meeting theme was "Bosses Night" each member introduced himself, his guests and his boss, if present. A cordial atmosphere was created for the main speaker, Dr. Tyrone Gillespie, assistant to the president of Dow Chemical Co., Midland, Mich.

Dr. Gillespie spoke of the world trade situation and particularly of the European trade pacts and how their long reaching implications will affect the imports and exports of the United States in the not too distant future. A question-and-answer period followed Dr. Gillespie's presentation, bringing out many points of current interest.

## PLANT TOUR

**Niles, Calif.**—Sixty members of the *Santa Clara Valley* Section including their wives and guests went on a tour through the Pacific States Steel Corp. plant in Niles on Friday evening, Dec. 20, 1957. Everyone expressed an opinion that the tour was very interesting and worthwhile. Company officials explained how the mills produce structural shapes to very close tolerances. An outline was made of the company's expansion which includes a blast furnace.

## HEAVY WELDMENTS

**Alliance, Ohio**—The November meeting of the *Stark Central* Section was held at the Virginian Restaurant in Alliance on Nov. 13, 1957. "Chris" Floyd [M], of Babcock & Wilcox Co. of Barberton, was the speaker. Mr. Floyd spoke on "Heavy Weldments."

The talk described many of his company's products such as stationary and marine boilers, atomic pressure vessels and anything else that no one wants to do. Mr. Floyd supplemented his speech with slides depicting some of the "trouble spots" that have arisen in the manufacture of their products.

Earlier that day, Mr. Floyd had given a two-hour lecture to a class of Babcock & Wilcox men and he continued with an "off-the-cuff" discussion of the subject. Mr. Floyd's thorough and varied background was clearly evident in his complete analysis of all the illustrated problems.

## DESIGNING FOR WELDING

**Syracuse, N. Y.**—The Dec. 11, 1957 meeting of the *Syracuse* Section was held at the Onondaga Hotel. The coffee speaker was Eugene Bloom, treasurer of the Technical Societies Council of Greater Syracuse, who explained how this organization could be of benefit to the forty-five or more technical societies of greater Syracuse.

"Product Design for Welding," was the topic for the technical meeting, presented to forty very interested members and guests by John Mikulak [M], assistant to the vice-president in charge of manufacturing of the Worthington Corp. Many weldments of modern design were shown by slides while Mr. Mikulak explained the designs and welding processes, answering many questions during and after his talk. He also stated that many weldments are adapted from castings, requiring the welding of too many parts.

After the meeting a door prize was given and a luncheon was served.

## PLANT TOUR

**Grand Rapids, Mich.**—The regular monthly meeting of the *Western Michigan* Section was held on Monday evening, Dec. 16, 1957, at the Varsity Grille in Grand Rapids. The meeting was held one week earlier due to the Christmas Holidays.

The dinner was a very well prepared Smorgasbord prepared by Mr. Vander Wal of the Varsity Grille. Present were 85 members and guests for the dinner and plant tour which followed.

The plant tour was at the Fisher Body Division of General Motors Corp. Plant No. 1 in Grand Rapids. The tour was under the direction of Ralph Bergsma of the Fisher plant. The members and guests were escorted through the stamping, welding and shipping departments, as well as the tool and die room.

This proved to be one of the Section's most interesting meetings.

## MAGNETIC-FLUX WELDING

**Worcester, Mass.**—On Dec. 2, 1957 the *Worcester* Section held its December dinner meeting at Nick's Grille with 47 at dinner and 51 attending the meeting.

Speaker at the meeting was Jack Douglas of Linde Co., Boston office. His subject was entitled "Unionarc Welding with Magnetized Flux and $CO_2$ Gas Envelope."

Mr. Douglas used slides to illustrate his subject and answered questions from the floor as he went along. In this way, the meaning and purpose of each view was thoroughly explained before advancing to the next. Quite a number in the audience were interested in this process; so, the questions were many, varied and to the point. When Mr. Douglas had concluded, there was very little about this process to be left to the imagination.

Finally he showed a reel of film, taken at Caterpillar Tractor Co., Peoria, Ill., showing this magnetic-flux welding method working on production. Those in attendance enjoyed a good meal and a very intelligent lecture.

# New Members

*Effective December 1, 1957*

*MEMBERSHIP CLASSIFICATION*

A Sustaining Member B Member C Associate Member
D Student Member E Honorary Member F Life Member

Total National Membership

| | |
|---|---|
| *Sustaining Members* | *175* |
| *Members* | *6,132* |
| *Associate Members* | *6,152* |
| *Student Members* | *162* |
| *Honorary Members* | *9* |
| *Life Members* | *15* |
| *Total* | **12,645** |

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Thompson, Edward R. (B)

**BIRMINGHAM**

Fisher, Robert E. (C)

**BOSTON**

Bloodsworth, Frederick L. (P)
Gilberg, Sheldon Robert (C)
Saunders, Nelson T. (B)
Wixon, Joseph T. (C)

**BRIDGEPORT**

DeMattia, Andrew (B)

**CANADA**

Eberts, James E. (B)

**CAROLINA**

Morgan, James C. (C)
Puryear, Earl V. (B)
Selisker, Raymond E. (B)

**CHICAGO**

Howell, J. G. (B)
Love, William W. (C)
McMills, James C. (C)
Zalfen, Fritz (B)

**CLEVELAND**

Butler, Stephen A. (B)
Graves, Bryan E. (C)
Shepherd, William V. (B)
Smith, Robert Craig (C)
Strom, Walter C. (C)
Stupka, Charles R. (B)

**COLORADO**

Onofrey, John E. (B)

**COLUMBUS**

Bias, Thomas O. (B)
Bradley, James W. (D)
Lott, Donald (D)
Malfe, James W. (C)
Murrey, G. K. (B)

**DALLAS**

Collins, J. C. (B)
Guy, H. N. (B)

**DAYTON**

Foster, William C. (C)

**DETROIT**

Vallie, William J. (C)

**HARTFORD**

Bachta, Joseph (B)
McKinnon, William (B)

**HOUSTON**

Barbour, Robert W. (D)
Ebner, M. F. (B)
Jones, Mack F. (B)
Knight, E. F. (B)
Markham, Charles E. (D)
Morrogh, Rodric (C)
Perez, Ovidio (B)
Pierce, Charles B. (B)
Shapple, Rodney D. (D)
Smith, Doyle E. (B)
Stapleton, John L. (B)
VanMeter, Ted C. (B)
Ware, James Ronald (B)

**INDIANA**

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**IOWA**

Feil, Adolph (C)

**IOWA-ILLINOIS**

Ahrens, Hans, Jr. (B)
Jetter, William W. (B)
Ravenscratt, William H. (B)

**KANSAS CITY**

Jones, Howard (B)

**LONG ISLAND**

Ghastin, Charles S. (C)
Gregory, Chester (C)
Perley, George K. (C)

**LOS ANGELES**

Austin, Asher H. (D)
Ballentine, William L., Jr. (B)
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Davis, Clarence (D)
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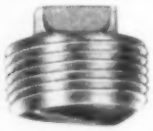

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**SAGINAW VALLEY**

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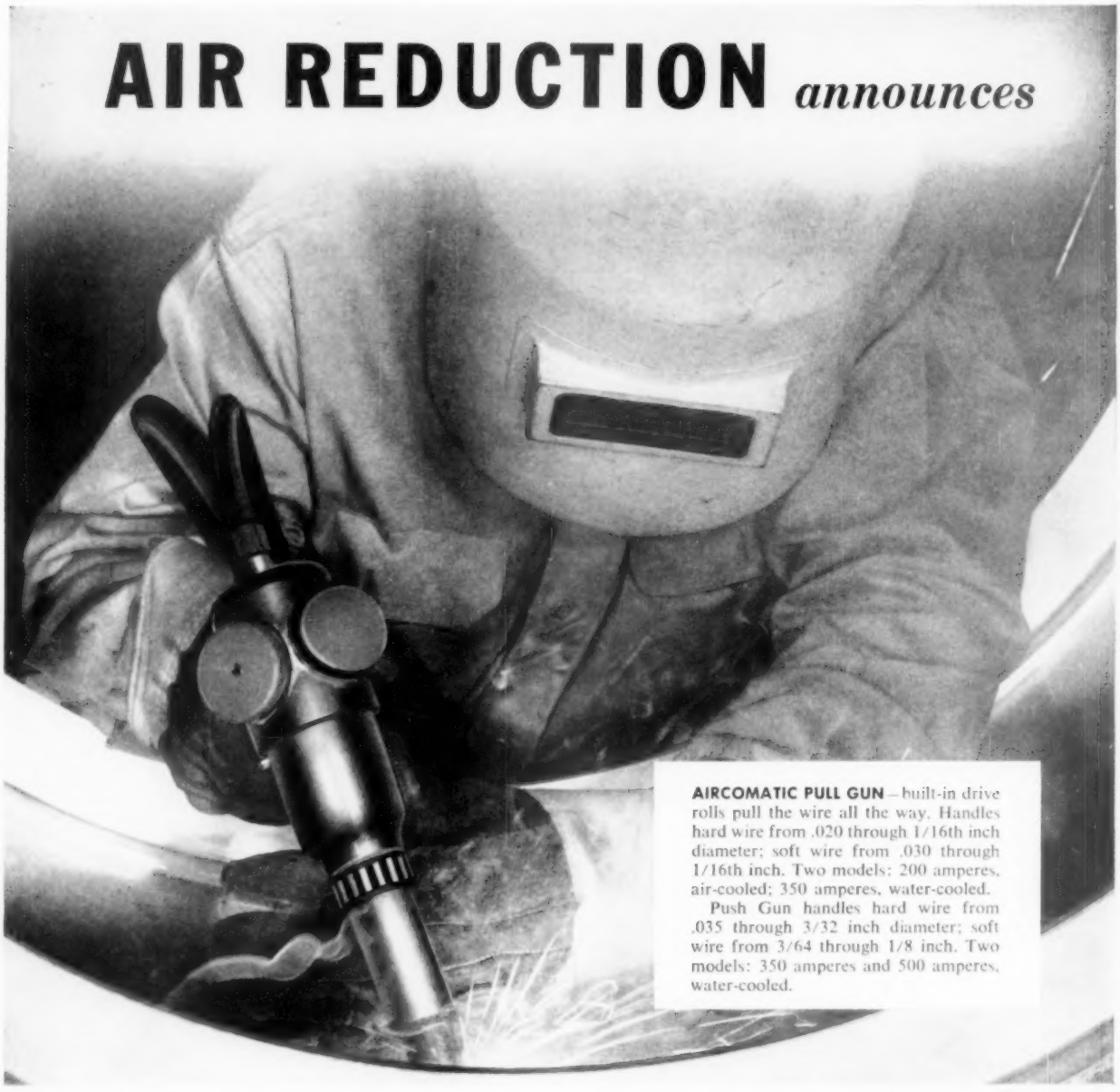

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# ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25c from the Commissioner of Patents, Washington, D. C.

2,794,899—Apparatus for and Method of Forming P-N Junction Devices—Alexander R. F. Plummer, Wembley, England, assignor, by mesne assignments, to The General Electric Co. Ltd., Wembley, England.

Plummer's patent relates to a method of bonding a wire to a fused bead of material which forms a P-N junction with a body of semiconductive material and the method comprises placing an end of the wire in contact with the surface of the bead and applying heat to the wire spaced from the end while maintaining the end thermally shielded from the heat except by conduction through the wire so that only a portion of the bead adjacent the wire end is melted. This wire end is pressed into the melted portion until immersed therein and when the melted portion is cooled, bond the wire thereto.

2,794,900—Water Cooled Electric Welding Assembly—Robert B. Width, Detroit, Mich., assignor to Welding Sales & Engineering Co., Detroit, Mich., a corporation of Michigan.

Width's patent relates to a specialized water-cooled electric welding electrode assembly.

2,794,901—Automatic Vertical Welder—Lynn J. Christensen, Salt Lake City, Fred J. Jensen, Kearns, and Darwin C. Christofferson, Salt Lake City, Utah, assignors to Chicago Bridge & Iron Co., a corporation of Illinois.

This special welder is to weld a substantially vertical seam between adjoining plates. It includes a carriage having means for supporting it from the plates, a welding unit carried by the carriage, which unit has an electrode and a mold thereon for retaining a puddle of molten material. The carriage is supported and guided for vertical movement along the desired vertical seam so that a continuous vertical weld is made. Other means urge the mold into contact with the surface of the plate at the vertical seam during vertical movement of the mold and associated welding means.

2,794,902—Signal Bond Protecting Device—David R. Bracken, Charleston, Ill.

Bracken's patent is on a protector for use in shielding railway track signal bonds during the replacement of worn away rail metal at the joint of adjacent aligned rails. The welding protector includes a heat and electrical arc resistance material pressed against the side face of the upper flange of the adjacent rail while welding action is affected thereon.

2,795,039—Method of Frictionally Welding A Tube to A Metal Object—Everett C. Hutchins, Dayton, Ohio, assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

Hutchins' patent is on a method of joining the ends of ductile tubing and includes the step of telescoping the ends of the tubing to be joined and confining the outer surfaces of the tubing adjacent the telescoped ends. A tool is rotated at a surface speed of about 300 fpm and is moved axially through the interior of the tubing at the overlapped ends to frictionally heat and squeeze the telescoped ends radially into a firm welded joint.

2,795,040—Joining Metals Having High Temperature Melting Points—Damon C. Antel, Trafford, and Herbert E. Ricks and August P. Colaiaco, Pittsburgh, Pa., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

The present patent relates to a process of joining metal members having a melting point greater than 1400° C. Initially a uniform coating of metal phosphide of a metal selected from at least one of the group consisting of cobalt and nickel is deposited on one of the members in the area where the members are to be joined. The members are heated to a temperature of between 800 to 1400° C in a protective atmosphere to cause the coating to flow. Heating in the protective atmosphere is continued to drive off substantially all of the phosphorus from the phosphide and thereby join the members with a metal bond having a low phosphorus content and of a much higher melting point.

2,795,520—Extruded Phosphorus-Silver-Copper Brazing Alloys—Richard E. Ballentine, Buffalo, N. Y., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

A brazing member in rod form is disclosed by the present patent. Such rod is composed of an alloy of from 6 to 9% of copper, from 7 to 8% phosphorus, and the balance being copper. The member is made ductile by being extruded to shape while at a temperature of between 475 to 600° C.

2,795,688—Welding Electrode Tip—David John McCaffrey, Sr., College Park, Md.

The present patent is on a welding electrode for use with a spot welding machine of low voltage and low pressure. The electrode includes a base made from copper and having a stainless steel tip fused thereto. The electrode can be used for welding of aluminum, but can be used as an ordinary electrode for spot welding any metal when the stainless-steel tip is worn away or removed.

2,795,689—Automatic Pipe Welding Apparatus—Louis C. McNutt, Scotch Plains, N. J.

This patent is on apparatus for welding together two large pipe ends. Suitable support devices are provided and are adapted to be attached to one of the pipe ends and a ring type gear is rotatably carried by a supporting device. A holder carrying a tungsten electrode along with an inert-gas supply is provided for establishing a welding arc. Another holder is provided and is suitably supported and carries a welding wire for providing the weld material at the arc. Motor means are operatively connected to the ring gear for turning it around the pipe and switch means are present for automatically controlling the operation of the motor and the welding arc.

2,796,508—Method for Producing Non-ferrous Continuous Weld Tubing—Keith M. Holman, Fermore B. Cooper and Frank E. Bergman, Spokane, Wash., assignors to Aluminum Supply Co., Spokane, Wash., a partnership.

The present patent relates to the production of continuous weld aluminum tubing and includes the steps of removing oxide from the marginal edge portions and edges to be welded on an aluminum strip and forming the strip into a continuous tube with the edges abutting. Heat is applied to the abutting edges by means of an inert-gas-shielded arc to melt the edges and cause them to coalesce and simultaneously applying inert gas to the underside of the weld area. The molten coalesced edges are supported within the tube and are subjected to a transverse upset when heated to a molten state and returning to the solid condition. Then the weld is subjected to a transverse cold upset to eliminate minute transverse cracks.

2,796,509—Means for Electro-Erosion—Leslie Reginald Blake, Rugby, England, assignor to the British Thomson-Houston Co. Ltd., a British Company.

This apparatus is for electrically eroding a workpiece of metal by means of rapidly repeated electrical discharges between the workpiece and the tool electrode. A capacitor is connected to the tool electrode and workpiece and to an electric power circuit, and a charging circuit is provided for recharging the capacitor after each discharge. The charging circuit is substantially purely inductive and a part of its inductance is provided by a coil which serves to energize an electromagnetic vibrator in synchronism with the charging cycles of the capacitor. This vibrator is connected to the tool electrode to decrease and increase the distance between the electrode and workpiece to vary cyclically the resistance in the discharge gap to initiate a discharge of considerable energy therethrough at the end of each recharge of the capacitor.

2,796,510—Method of Resistance Welding Sandwich Panels—Thomas A. Herbert, Jr., Chula Vista, Calif., assignor to Rohr Aircraft Corp., Chula Vista, Calif., a corporation of California.

The present patent relates to the production of a metallic sandwich panel wherein a thin metallic skin having a thickness of from about 0.002 to 0.010 of an inch is applied to an end of a metallic cellular core. The apparatus includes pressing means composed of metal having a high electrical conductivity for forcing the metal skin against the ends of cells in the core, and means connect to the pressing means and to a metal plate that supports the cellular core so as to pass an electrical welding current through the skin and core.

2,796,511—Method and Apparatus for Joining Wires by Brazing—Maurice G. Steele, Rome, N. Y., assignor to Rome Cable Corp., Rome, N. Y., a corporation of New York.

Steele's patent relates to a method comprising clamping two wires in end-to-end relation and, while chilling the wires, the ends of the wires are heated in a substantially enclosed space. A pellet of brazing material is positioned between the ends of the wires and at least one of the wires is moved a predetermined distance toward the other to braze the wires together.

2,796,513—Stud Welding Apparatus—Frank K. Kelemen and Ralph K. Ritter, Haddonfield, N. J., assignors to KSM Products, Inc., Merchantville, N. J., a corporation of New Jersey.

This patent upon stud welding apparatus includes a stud holding means mounted for movement in both lift and plunge directions. Special means are provided in the apparatus for controlling movement of the parts in the different directions.

2,796,514—Welding Electrode Holder and Electrode Therefor—Arthur F. Wood, Indianapolis, Ind., assignor to P. R. Mallory and Co., Inc., Indianapolis, Ind., a corporation of Delaware.

This novel welding electrode holder includes a barrel having a threaded portion at one end and an adaptor nut is positioned on the threaded section of the barrel and has an inner shoulder engaging a similar shoulder on an electrode. End faces of the barrel and electrode are in pressure contact and in direct electrical connection with each other so as to carry heavy welding currents at a negligible voltage drop and to support extremely high welding forces in the axial direction. Other means are provided for circulating a coolant fluid into a coolant hole provided in the electrode and a retracting tube is positioned in the barrel around the inlet tube for circulation of cooling liquid in the electrode and barrel.

2,796,843—Ceramic Welding Ring—Willis D. Kleppinger, Plainfield, N. J., assignor to Steatite Research Corp., Keasbey, N. J., a corporation of Delaware.

A liner device for use in welding two pipe ends together is disclosed in the patent. The liner includes a ring of shatterable ceramic material adapted to fit within the pipe sections to be welded, and a plurality of elastic strip metal retaining means is carried by the ceramic liner and protrude beyond the circumference of the liner ring. Spacing clip means are also provided for contacting opposite side portions of the ceramic ring to position it for engaging the end edges of the pipes to be welded together and space them apart by strip metal retaining means provided.

2,797,255—Liquid-Cooled Welding Cable Assembly—Frederick S. Wreford, deceased, late of Detroit, Mich., assignor, by direct and mesne assignments, to Gar Wood Industries, Inc., Wayne, Mich., a corporation of Michigan.

This patent is on a flexible cable unit for welding equipment and it includes a tubular insulating casing, and a plurality of flexible welding current conductors within the casing. Terminal heads are connected to the opposite ends of the conductors in the cable unit. A flexible cooling liquid conduit is disposed in and extends lengthwise of the cable unit and connects to special cooling liquid passageways provided in the terminals in the cable unit.

2,797,299—Method of Forming Serrations at the Back of the Blade of Cutting Elements—John P. Hill, Detroit, Mich., assignor to Goodard & Goodard Co., Detroit, Mich., a corporation of Michigan.

Hill's patent is on a method of forming parallel serrations in one surface of a cutting blade. A rotary electrode is provided and has circumferential serrations therein, which electrode is rotated about its axis. The cutting blade and electrode are traversed in a direction perpendicular to the axis of the electrode while maintaining constant spacing between the axis of the electrode and the surface being serrated to form serrations in the blade of uniform depth. A high frequency electric discharge is established between the electrode and the blade.

2,797,300—Welding—Lowell H. Hawthorne, Verona, N. Y., assignor to Revere Copper and Brass Inc., Rome, N. Y., a corporation of Maryland.

Hawthorne's patent is on the subject of welding copper and copper base alloys. A copper welding wire is arc melted and molten metal is applied to the joint to be welded in a shielding atmosphere of inert gas. The welding wire contains tin within the range of approximately 0.1 to 1.5% for providing high fluidity in the molten metal and the weld wire contains titanium within the range of approximately 0.05 to 0.3% to provide low surface tension in the molten weld material. The balance of the welding wire is essentially all copper.

2,797,301—Welding Torches—Francis William Copleston, London, England, assignor to the British Oxygen Co. Ltd., a British company.

This patented welding torch includes a body portion, a conduit within the body portion, and an annular sealing surface on the body portion but inclined in an acute angle to the longitudinal axis thereof. A nozzle unit is also provided and has a conduit within it, and an annular sealing surface is provided on the nozzle unit but inclined at an acute angle to the longitudinal axis. Clamping means are provided for holding the annular sealing surfaces together to allow adjustment of the relative angular positions of the body portion and nozzle unit without slackening of the clamping means.

2,797,302—Low Voltage Percussion Welder with Auxiliary Arc Striking Circuit—James L. Smith, Basking Ridge, N. J., assignor to Bell Telephone Laboratories, Inc., New York, N. Y., a corporation of New York.

This patented percussion arc welding system includes an energy storage circuit which includes a high voltage, low capacity portion, and a low voltage, high capacity portion and a diode rectifier interposed between the portions to isolate the low voltage from the high voltage portions and to switch from one to the other as the high voltage portion is discharged. Thus as the pair of electrodes are brought together at an appreciable velocity, the arc will be initiated by the high voltage portion of the energy storage circuit even when substantial electrode separation exists. Thereafter the arc is sustained by the low voltage portion of the storage circuit until the arc is extinguished by a firm closure of the electrodes.

2,797,303—Method of and Apparatus for Producing Hermetically Sealed Cartridges—Henry Kershaw, Belleville, N. J.

This patent relates to a method and apparatus for producing a hermetically sealed cartridge for transistors or the like. The special features of the apparatus include means for applying a welding current to certain contacting parts to be welded while they are subjected to clamping engagement. Other means connect to an inner tubular electrode for supplying an inert gas into such electrode.

2,797,304—Methods of Welding—James Arthur Donelan, West Harrow, England, assignor to the General Electric Co., Ltd., London, England.

Donelan's welding method relates to aluminum or aluminum alloys and in which metal is welded at a seam in a butt joint to form a joint of predetermined

depth and width transverse to the length of the seam. After the metal at the seam has cooled sufficiently to recrystallize, the whole length of the welded seam is remelted without the addition of further metal, but only melted to a smaller depth and across a smaller width than the predetermined depth and width. Thereafter the remelted seam is allowed to cool.

2,797,305—Cooling System for Electrode Tips—Chester A. Czohara, Chicago, Ill., assignor to International Harvester Co., a corporation of New Jersey.

This patent relates to a welding gun including an electrode tip holder, and an electrode tip disposed in a recess in the holder and extending therefrom. Flexible conduit means are provided within the tip holder and electrode tip for circulating cooling fluid therethrough in association with enlarged bores in which the conduits are received.

2,797,306—Welding Gun Structure—Norman C. Qualey, Minneapolis, Minn., assignor to Northern Ordnance Inc., Minneapolis, Minn., a corporation of Minnesota.

Qualey's patent is on a welding torch including a handle having a nozzle secured to a terminal portion thereof by a coupling member. A pipelike protecting member is secured to the torch assembly and projects beyond the end of the nozzle and an associated gas discharge tube so as to receive any damage resulting from the heat of welding so that the nozzle is not damaged thereby.

2,797,307—Welding Electrode Holder—Leopold Edward Goodwin, Toorak, near Melbourne, Victoria, Australia.

This patented welding electrode holder includes a body member and a handle attached to the body member at an angle thereto. A trigger is provided on the body member and connects to means therein for releasing an electrode gripping member. The handle and trigger are so arranged that the trigger may be actuated by the hand holding the electrode holder.

2,797,352—Means and Method for Improving the Starting of an Electric Arc—Harold Spencer Payne, Cleveland Heights, Ohio.

Arc welding apparatus is disclosed in this patent and includes means for moving an electrode toward a workpiece prior to the striking of an electrical arc. Other means are present in the apparatus to superimpose on this movement, prior to the striking of the arc, a repetitive movement so that electric contact of the electrode end and workpiece will be facilitated. Other means stop such repetitive movement when the arc is struck.

2,798,141—Means and Method for Making a Vacuum-Tight Weld by Induction Heating—Henry C. M. Longacre, Glen Oaks, N. Y., assignor to Sylvania Electric Products, Inc., a corporation of Massachusetts.

This process relates to the induction heating welding of a first metal member having a first melting temperature and a first thermal expansion coefficient and a second metal member having a second and higher melting temperature and a second and lower coefficient of expansion. A projection on the first member is forced into a hollow section of the second member to form a common peripheral contact therebetween and a high-frequency magnetic field is established around the second member so that the heating effects are confined to a selected weld area. Such area is heated to a temperature that is at least equal to the first melting temperature but is below the second member melting temperature. The field is established for a short interval sufficient to permit weld formation and insufficient to cause appreciable heating of the member surfaces adjacent to the weld area.

2,798,145—Arc Welding Torch with Adjusting Means for Nondepositing Electrode—Edward J. Vogel, Chicago, Ill., assignor to the Liquid Carbonic Corp., Chicago, Ill., a corporation of Delaware.

A specialized arc welding torch of the type indicated is disclosed in the present patent.

2,798,146—Bellows Welding Apparatus—Milton H. November, East Orange, N. J., assignor to Breeze Corp., Inc., Newark, N. J., a corporation of New Jersey.

November's patent is on apparatus for welding disk-shaped elements into a bellows assembly. A welding station is carried by a base plate, and a clamping ring is disposed in each of a pair of oppositely positioned frames. Other means are provided for moving the rings and frames up and down relative to the base plate and welding station.

2,798,187—Device for Controlling the Welding Times and Intervals in Resistance Welding Apparatus—Karl Walter Hess, Frans Hendrik De Jong, and Lambertus Wilhelmus Roosendaal, Eindhoven, Netherlands, assignors, by mesne assignments, to North American Philips Co., Inc., New York, N. Y., a corporation of Delaware.

In this patent, a first capacitor and a first discharge tube are provided and means are provided for charging the capacitor through a resistor. The capacitor is connected to the tube to discharge through it during predetermined intervals to produce discharge pulses therein. Other circuit means are provided for applying control voltages to the tube to discharge the capacitor and the circuit means provide adjustable pulses which determine the duration of the welding cycle and the interval of welding time.

2,798,824—Coated Electrode Particularly Suited for Welding Dissimilar Metals—Pierre E. Le Grand, Plainfield, George R. Pease, Westfield, and Theodore E. Kihlgren, Berkeley Heights, N. J., assignors to the International Nickel Co., Inc., New York, N. Y., a corporation of Delaware.

This new electrode has a core wire containing about 14 to 17% chromium, up to about 3%, manganese and at least about 70% nickel together with quantities of other elements. The flux contains stated quantities of a number of other materials. The electrode is characterized by its adaptation for forming crack-free weld deposits when welding dissimilar metals.

2,798,927—Induction Flash Welder—Stanley Warren Lefcourt, Bronx, N. Y., and Robert Mayer, Havertown, Pa., assignors to Sylvania Electric Products, Inc., a corporation of Massachusetts.

A welding apparatus including a liquid container, a welding apparatus above the liquid in the container, and means movable vertically and having a support for a tube within the container are provided. The support is adapted to move upwardly to bring a portion of the tube into welding relation with respect to the weld apparatus and downwardly into cooling relation with respect to the liquid in the container. An electromagnet and timing means for operating the electromagnet are provided for controlling the movable support.

2,798,933—Apparatus for Making Wiring Conduits—Frederick W. Cummings, Pittsford, and Henry D. Mowers, Spencerport, N. Y., assignors to General Motors Corp., Detroit, Mich., a corporation of Delaware.

The present patent is on apparatus for forming an electrical conduit comprising a metal tube having individual conducting wires the diameters of which are substantially smaller than that of the metal tube and with the conduit having filler material positioned therein throughout its length. A flat metal strip is progressively bent into tubular shape around the filler material and individual wires. Thereafter the diameter of the formed tube is reduced to the extent desired so as to exert appreciable pressure on the conducting wires and included filler material.

2,798,934—Electrical Spark Machining Devices—Marc Brunia, Pavillons-sous-Bois, France, assignor to Centre National de la Recherche Scientifique, Paris, France, a society of France.

Brunia's patent is on apparatus for machining by means of electric sparks. The apparatus includes a source of alternating current and magnetic ferro-resonant switching means arranged in the circuit to cause a unidirectional current peak in the circuit only on every alternation in one direction of the alternating voltage of the source. Thus unidirectional current discharges are produced without rectification through ordinary rectifying means.

2,798,936—Method of and Apparatus for Welding Contacts onto Relay Parts—Amos L. Quinlan, La Grange Park, Ill., assignor to Western Electric Co., Inc., New York, N. Y., a corporation of New York.

A method of forming contacts and percussively welding them onto articles is disclosed in this patent. A tape of contact material is moved through a path and the contact is sheared from the tape and transferred to a welding electrode. An article is provided in the path of movement of the welding electrode and contact thereon and the welding electrode and article are brought into contact to fuse the contact and article together by percussive engagement under an applied voltage.

# NEWS of The Industry

## Alloy Rods Promotes Pierce

John M. Pierce has been named to the post of western sales manager by E. R. Walsh, III, vice-president in charge of sales for Alloy Rods Co. Mr. Pierce will be directly responsible for all sales activities and distributor accounts in

John M. Pierce

the eleven western states. He was formerly field representative for the company in the Chicago area and more recently in the Los Angeles area. Mr. Pierce will make his headquarters at the Alloy Rods Co. El Segundo plant.

He is a member of the AMERICAN WELDING SOCIETY.

## Lincoln Assigns District Salesmen

Paul McGonigle, Richard R. Gould and Jerry Weiss have recently joined the Lincoln Electric Co.'s district offices at Boston, Mass.; Pittsburgh, Pa.; and Detroit, Mich., respectively. All three of these men completed a one-year training program at Lincoln's plant in Cleveland, Ohio, before moving to their present assignments.

In moving to Boston, Mr. McGonigle is returning to familiar territory, as he is a native Bostonian and a graduate of Holy Cross University. He also received a master's degree from Wharton Graduate School of Finance. Two year's service in the U. S. Army preceded his affiliation with Lincoln.

Mr. Gould of Lakewood, Ohio, received an engineering administration degree from Case Institute of Technology. He is assigned to the Pittsburgh office which covers southwestern Pennsylvania and parts of Ohio and West Virginia.

Mr. Weiss, a native of Peoria, Ill., joined the company from Keystone Steel and Wire Co. of Peoria where he was a project engineer. He studied mechanical engineering and advertising and sales at Bradley University.

Messrs. McGonigle and Gould are members of the AMERICAN WELDING SOCIETY.

## Eutectic Opens Los Angeles Branch

A new, modern warehouse-service center, housing complete service, testing, warehousing and shipping space to serve

Los Angeles area industry has been established by Eutectic Welding Alloys Co., Inc.

The opening of the new "Eutectic" warehouse-service center at 5348 Jillson St., Los Angeles, was announced by Rene D. Wasserman, president of Eutectic Welding Alloys Corp.

The new Pacific warehouse-service center will be operated by R. C. Wilcox, a veteran with long experience in the metal-joining field, including several years as manager of the Eutectic warehouse-service center in Atlanta, Ga.

## M&T Sells Thermit Welding Business

Metal & Thermit Corp. announces the sale of its thermit welding business to Reade Manufacturing Co., Inc., of Jersey City, N. J.

In announcing Metal & Thermit's retirement from the thermit welding field, H. E. Martin, its president, stated that this action reflected in part the company's over-all growth plans which call for concentration of activities and expansion in the production and marketing of chemicals, metals and are welding electrodes and equipment.

Beginning Dec. 2, 1957, Reade Manufacturing Co., an established firm in the railway supply and powdered metals fields, began supplying materials and equipment for thermit welding as well as technical assistance on thermit welding problems.

## Airco Opens New Store

Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y., has just opened a new store at 1000 Yuma Street, Denver, Colo., it was announced by J. O. McElligatt, district manager.

Argon, helium and a complete line of Airco oxyacetylene, inert-gas and electric welding equipment, electrodes and supplies will be available from this new sales outlet. The location also offers technical assistance and equipment repair service.

## A. O. Smith Names Vice-Presidents

The Board of Directors of the A. O. Smith Corp., Milwaukee, Wis., has named 11 of the company's executives as new vice-presidents. Those appointed are M. E. Morgan, W. W. Higgins, S. E. Wolkenheim, R. F. McGinn, J. H. Brinker, John S. Randall, W. W. Stake, George P. Hough, L. M. Keating, Allen O. Dragge and Walter H. Porth.

# COMING EVENTS

*A Calendar of Welding Activity*

AWS National Meetings

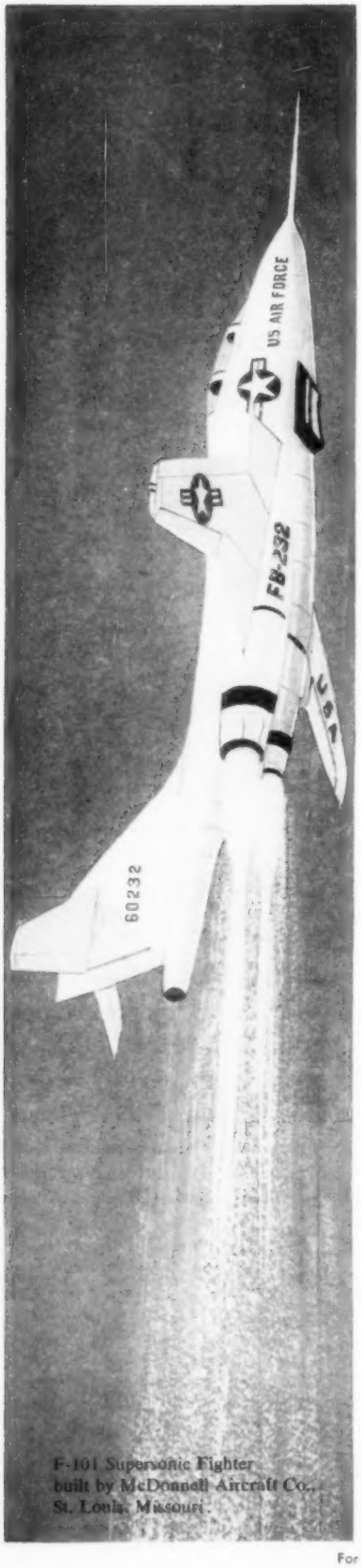
1958 Spring Meeting and Welding Show:
April 14–18, Statler Hotel, St. Louis, Mo.

IAA

March 19–21. Fifty-eighth Annual Convention, Bellevue Stratford Hotel, Philadelphia, Pa.

NWSA

May 5–8. 14th Annual Convention. Americana, Miami Beach, Fla.




F-101 Supersonic Fighter built by McDonnell Aircraft Co., St. Louis, Missouri.

# Aluminum dip brazing solves fabrication problem for fighter oil-cooling unit

The plate-type lube oil cooler of the F-101 supersonic fighter must cool the lifeblood of its engine dependably and efficiently in rarified atmospheres. Its design, consisting of a complex perforated grid enclosed in a crimped sheet envelope, demands strength to withstand 400 psi internal oil pressure. *Thousands of tiny grid surfaces had to be joined firmly to the plate envelope with the strength of a single unit.*

A joining problem such as this could only be solved by the aluminum dip-brazing technique. In this instance, Alcoa No. 6061 alloy was joined with Alcoa No. 22 brazing sheet by dipping in molten flux. Result, an all-aluminum unit of high corrosion resistance with strong and uniformly smooth joints.

Aluminum brazing offers many design approaches and advantages worth considering in the planning stage. Complicated assemblies with inaccessible joints can be made as a single unit which is smaller, lighter, more efficient *and* lower in cost. Close tolerances in small parts are obtainable—joints may be built up to desired strength.

Get in touch with Alcoa *before* you plan. We'll supply the information you need for welding, brazing or soldering aluminum. Contact one of the Alcoa distributors listed at the right or send for free information books and films on joining aluminum. Write to Aluminum Company of America, 1741-B Alcoa Building, Pittsburgh 19, Pennsylvania.

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ALCOA ALUMINUM WELDING PRODUCTS
ALUMINUM COMPANY OF AMERICA

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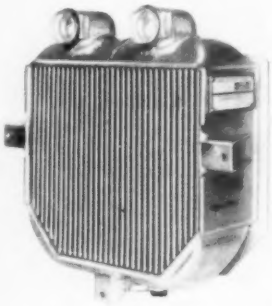
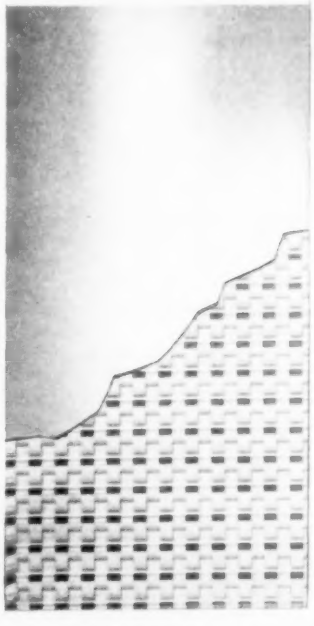
Plate-type aircraft lube oil cooler made by Clifford Manufacturing Co., Waltham, Mass., a division of Standard Thomson Corporation. Vertical plates and V-shape dividers or fins provide a heat transfer service of 32½ sq. ft. Oil is cooled by passage of air through these plates.



Cutaway of plate and interior grid through which oil flows.



For more details, circle No. 17 on Reader Information Card

*Want technical help* in welding, brazing or soldering aluminum? Contact your Alcoa sales office, listed under "Aluminum" in the Yellow Pages of your phone book.

*For immediate delivery* of Alcoa welding products, call your Alcoa outlet listed below. He carries a complete range of alloys and sizes.

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Hinkle Supply Co.

**CALIFORNIA**
Los Angeles
Ducommun Metals & Supply Co.
Pacific Metals Company, Ltd.
San Francisco
Pacific Metals Company, Ltd.

**COLORADO**
Denver
Metal Goods Corp.

**CONNECTICUT**
Windsor
Whitehead Metal Products Co., Inc.

**FLORIDA**
Jacksonville
J. M. Tull Metal & Supply Co., Inc.
Miami
J. M. Tull Metal & Supply Co., Inc.
Tampa
J. M. Tull Metal & Supply Co., Inc.

**GEORGIA**
Atlanta
J. M. Tull Metal & Supply Co., Inc.
Southern Oxygen Co.

**ILLINOIS**
Chicago
Machinery & Welder Corp.
Steel Sales Corp.
Moline
Machinery & Welder Corp.

**KENTUCKY**
Louisville
Williams and Co., Inc.

**LOUISIANA**
New Orleans
Metal Goods Corp.

**MARYLAND**
Baltimore
Southern Oxygen Co.
Whitehead Metal Products Co., Inc.
Bladensburg
Southern Oxygen Co.
Salisbury
Southern Oxygen Co.

**MASSACHUSETTS**
Cambridge
Whitehead Metal Products Co., Inc.

**MICHIGAN**
Detroit
Steel Sales Corp.

**MISSOURI**
Kansas City
Metal Goods Corp.
St. Louis
Metal Goods Corp.

**NEW HAMPSHIRE**
Nashua
Edgcomb Steel of New England, Inc.

**NEW JERSEY**
Harrison
Whitehead Metal Products Co., Inc.
Merchantville
Southern Oxygen Co.
Vineland
Southern Oxygen Co.

**NEW YORK**
Albany
Whitehead Metal Products Co., Inc.
Buffalo
Whitehead Metal Products Co., Inc.
New York
Southern Oxygen Co.
Whitehead Metal Products Co., Inc.
Syracuse
Brace-Mueller-Huntley, Inc.
Whitehead Metal Products Co., Inc.

**NORTH CAROLINA**
Asheville
Southern Oxygen Co.
Charlotte
Southern Oxygen Co.
Greensboro
Southern Oxygen Co.
Raleigh
Southern Oxygen Co.

**OHIO**
Cincinnati
Williams and Co., Inc.
Cleveland
Nottingham Steel & Aluminum Co.
Williams and Co., Inc.
Columbus
Williams and Co., Inc.
Toledo
Williams and Co., Inc.

**OKLAHOMA**
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Metal Goods Corp.

**OREGON**
Portland
Pacific Metal Co.

**PENNSYLVANIA**
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Edgcomb Steel Co.
Southern Oxygen Co.
Whitehead Metal Products Co., Inc.
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**TEXAS**
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Big Three Welding Equip. Co.

**UTAH**
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**VIRGINIA**
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Southern Oxygen Co.
Lynchburg
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Norfolk
Southern Oxygen Co.
Richmond
Southern Oxygen Co.
Roanoke
Southern Oxygen Co.

**WASHINGTON**
Seattle
Pacific Metal Co.

**WEST VIRGINIA**
Bluefield
Southern Oxygen Co.

**WISCONSIN**
Milwaukee
Machinery & Welder Corp.
Steel Sales Corp.

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## M & T Appoints Dealers

According to a recent announcement from Metal & Thermit Corp., 100 Park Ave., New York 17, N. Y., seven concerns throughout the country have been appointed dealers for Murex welding electrodes and M & T welding machines. The following firms have been named: Monson Welding Sales Inc., Syracuse, N. Y.; Ace Welding Supply Co., 1234 S. W. 29th St., Oklahoma City, Okla.; Webb City Metal Products Co., 1200 N. Peoria, Tulsa, Okla.; Acetylene Oxygen Co., Harlington, Tex.; Central Welding Supply Co. and Dunn Welding Equipment Co., both of Houston, Tex.; and Alabama Oxygen Co., 2028 Vanderbilt Rd., Birmingham, Ala.

## Lincoln Assigns Petty and Pierce

J. Howard Petty and Ronald C. Pierce have recently joined the Lincoln Electric Co.'s district office at Atlanta, Ga. Both of these men completed a one-year training program at Lincoln Electric's plant in Cleveland, Ohio, before joining the district office.

Mr. Petty, a native of Sulphur, Okla., received a degree in industrial arts from Oklahoma A & M. He also worked for the university as a welder.

Mr. Pierce of Cuyahoga Falls, Ohio, joined the company after receiving a degree in mechanical engineering from Purdue University.

## Ampco Announces Promotions

A broadening of its sales division at the management level to establish three sales managers' positions was announced by Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis.

The three new sales managers, all reporting to J. P. Henry, vice-president and general sales manager of Ampco, are F. E. Garriott, sales manager of finished products; I. S. Levison, technical products, and G. E. Brown, field sales.

Mr. Garriott, with Ampco since 1944, was former manager of the Weldrod & Wire Dept. Mr. Levinson was product manager in charge of Process Industries Sales and has been with Ampco since 1949. In his 11 years with the firm, Mr. Brown has held various sales assignments, the most recent being Wisconsin District Manager.

Wayne E. Claffin, a welding engineer who for 14 years has been associated with welding processes at Ampco Metal, Inc., Milwaukee, has been named product manager of the firm's Weldrod & Wire Dept. to succeed F. E. Garriott.

## American Messer Names Deily

American Messer Corp., 405 Lexington Ave., New York 17, N. Y., announces the appointment of Richard L. Deily as manager of sales for Messer oxygen cutting machines.

Mr. Deily has been associated with the steel and welding industry since graduation from Lehigh University in 1935. He was employed by the Bethlehem Steel Co. in various capacities in the cutting and welding field from 1936

Richard L. Deily

to 1949. Since 1949 he has been engaged in sales engineering work in the welding industry, starting as Pittsburgh district manager for Areway Equipment Co. Since 1951 he has been associated with the Air Reduction Co. in various capacities, most recently in charge of sales engineering of oxygen uses in the steel industry.

He was largely responsible for starting the Lehigh Valley Section of the American Welding Society and was later elected chairman. He is also a member of the American Institute of Mining, Metallurgical and Petroleum Engineers, the American Iron and Steel Engineers and the American Association for the Advancement of Science. He was also a member of the Handbook Committee on Oxygen Cutting.

As manager of sales for American Messer, Mr. Deily will set up a sales and service organization throughout the United States.

## RWMA Reports Second Best Year

With information covering the first ten months of 1957 now available, the Members of the Resistance Welder Manufacturers' Association have reported total shipments of about $27\frac{1}{2}$ million of machines and equipment during the current year. It is anticipated that the complete year will be about the same as 1955 volume, the second best year in the history of the industry.

### Victor Equipment Appointed by M&T

Metal & Thermit Corp., 100 Park Ave., New York 17, N. Y., announces the appointment of Victor Equipment Co., 840 Folsom St., San Francisco, California, as a distributor.

Victor Equipment, for many years a General Electric distributor, now sells and stocks the complete line of Murex electrodes and M&T welding machines.

### Budd Appoints Krasnow

Arthur L. Krasnow has been appointed sales manager, Eastern Region for the Nuclear Systems Division of the Budd Co., Dr. A. J. Stevens, vice-president and general manager of the division has announced.

Mr. Krasnow will cover the Eastern and Southeastern states and will be responsible for the sales in this area for radiography machines, radioactive sources and measuring devices utilizing radioactive materials. He is a graduate of the U. S. Naval Academy and Graduate School of Industrial Management at MIT.

Prior to coming to the Budd Company, he was sales manager for Baird Atomic Co., Cambridge, Mass.

### New England Distributor Moves

Arco Welding Supply Co., formerly of Melrose, Mass., has moved to new and larger quarters at 256-258 Highland Ave., Malden 48, Mass.

### Arizona Firm Named by Allis-Chalmers

C & C Welding Supply, Inc., Prescott, has been appointed a distributor for Allis-Chalmers motors, transformers and "Texrope" drive equipment in Yavapai, Mohave and Coconino counties in Arizona.

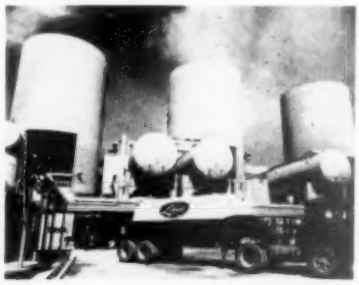
Charles E. McDaniel is owner of C & C Welding Supply, Inc.

### Westinghouse Names Frailey

Henry F. Frailey has been named operations manager for power and special purpose tubes. The announcement was made by B. W. Sauter, general manager of the Westinghouse Electric Corp. electronic tube division, Elmira, N. Y. Mr. Frailey will be responsible for the design, development, engineering and manufacturing of these tubes.

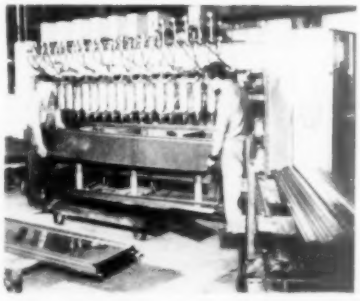
A graduate of Notre Dame, Mr. Frailey has been with the division since 1951, first as a supervisor of manufacturing engineering and then as superintendent, of the cathode-ray tube department.

### NEW LINDE PLANT "ON-STREAM"



Present site of Linde operations in Ashtabula, Ohio, where the newly-expanded facilities went "on-stream" January 1st to produce an additional 115,000,000 cu ft of oxygen per month

### BUILDS SHELF-CONFIDENCE



Designed and built for its own use by Standard Pressed Steel Co., Jenkintown, Pa., this 20-gun, special-purpose series, resistance spot welder allows two men to turn out 180 side-panel Erectomatic shelving assemblies an hour. This compares with 16 assemblies an hour when rocker-arm, individual spotwelders were used. Versatile controls allow operator—in a matter of seconds—to select any combination of guns from 1 to 20, for making simultaneous spotwelds at intervals as close as 6 in. Here, operators are shown reversing 7-ft panel in welder, using 16 guns to spotweld shelving uprights to sheets. The welder can handle lengths up to 123 in.; thicknesses to 0.172 of an inch. SPS is developing alternate dies to permit adapting welder for use on other components of the new fast-assembly Erectomatic shelving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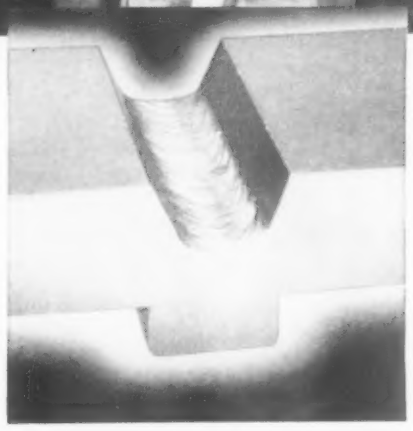
# Weldynamics

## ARC WELDING AT WORK CUTTING COSTS



## A special Jetweld for deep groove welds

Jetweld 2 is a special electrode designed particularly for groove welding. The high deposition rate gives maximum speed in fabrication. The excellent wash-up characteristic and complete freedom from undercut makes the slag easy to remove. Deposits are uniformly of X-ray quality.

No electrode gives faster welding and lower cleaning time. Try Jetweld 2 in your shop.

Lincoln men, trained in Weldynamics, will help you select the best electrode, machine and procedures for lowest welding costs.

Write for Bulletin 7000.1, New Weldirectory of Lincoln Mild Steel Electrodes.

*The World's Largest Manufacturer of Arc Welding Equipment*

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**THE LINCOLN ELECTRIC COMPANY, DEPT. 1937, CLEVELAND 17, OHIO**

For more details, circle No. 19 on Reader Information Card

## LINCOLN SUBSIDIARY BREAKS GROUND IN FRANCE

The mayor of Rouen, France, places, in the cornerstone of The Lincoln Electric Co.'s new French plant, a scroll recording the occasion of the starting of construction. Among the spectators are James F. Lincoln, Board Chairman of Lincoln, and A. R. Edwards, President of Armco International, export representatives for Lincoln. Lincoln's French subsidiary, La Soudure Electrique Lincoln, will operate the plant

## Airco Completes New Plant in Texas

Latest addition to the fast-growing industrial community at Arlington, Tex., between Dallas and Fort Worth, is

the recently completed $400,000 gas-producing plant of the Air Reduction Sales Co., a division of Air Reduction Co., Inc.

Included at the plant, which is primarily designed to produce high purity oxygen and nitrogen, are centralized stores and warehouse facilities for other major Air Reduction products including acetylene, argon, calcium carbide and welding supplies and equipment.

With the opening of the new plant at Arlington, district offices of the Air Reduction Sales Co. which have previously been located elsewhere have been transferred to the site. C. T. Burggraf is District Manager.

Functions and facilities of the Air Reduction gas-producing plant previously located at Dallas have also been moved to Arlington. Harry Melick, who until the move had been in charge of the Dallas plant, will be superintendent of the new facility at Arlington.


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Alloys and Fluxes for Joining ALL METALS ALL METHODS

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They Save On:

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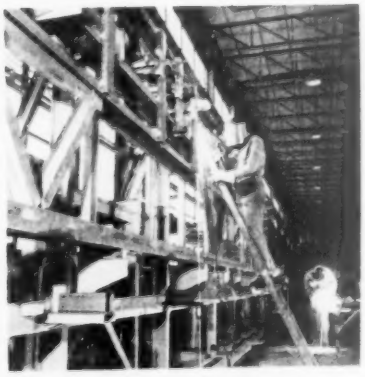
Seldom cost as much as 1% of savings made!

Look for this trade-mark at at your Welding Supply Distributor's. All metals. All methods. All-State is your assurance of these advantages when you buy. Ask for new Instruction Book on 62 alloys and fluxes.

ALL-STATE WELDING ALLOYS CO., INC., WHITE PLAINS, N. Y.

For more details, Circle No. 20 on Reader Information Card


## JOINING OF STRUCTURES SPEEDED

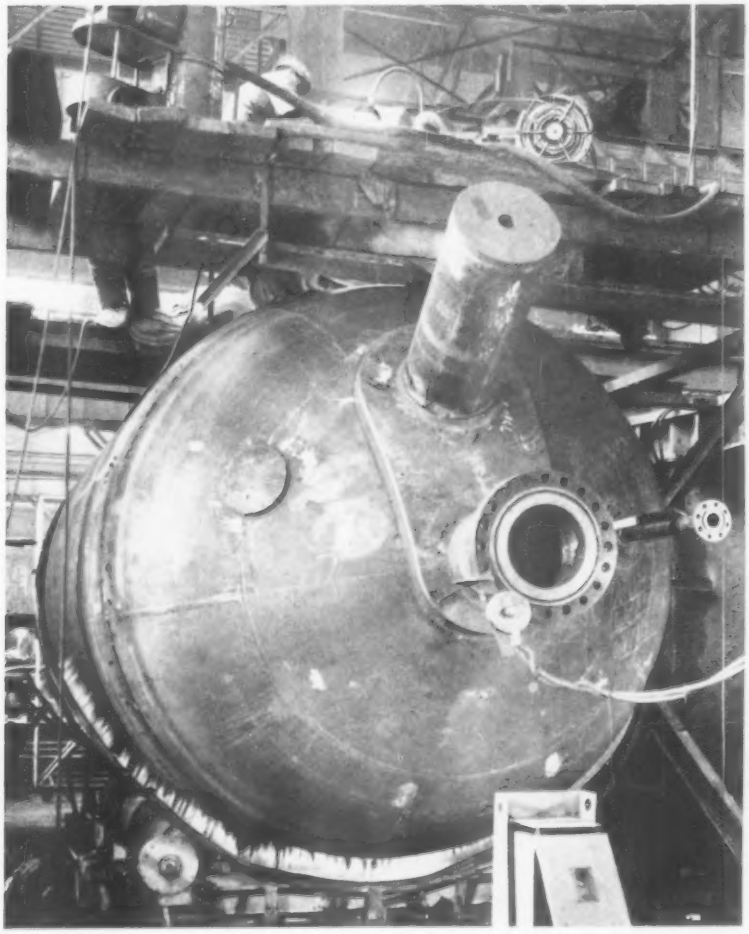


This giant 45-ft fixture employed by Wagner Brothers' Equipment Division, Detroit, to assemble and tack weld plating machine carriages, reduces assembly and welding time nearly 60%

# For any stainless welding job

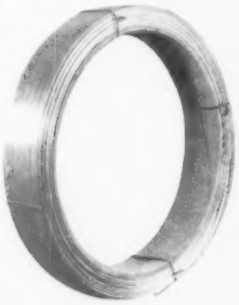
SPECIFY *Drawalloy* CORPORATION

## Stainless Steel Welding Wire



Spooled for Inert Gas Shielded Metal Arc Welding

Coiled for Submerged Arc Welding



Cut Lengths for Inert Arc Welding

Specify Drawalloy "quality controlled" stainless steel welding wire for *your* next "quality weldments." Your greatest advantage is experience . . . our experience in producing wires for welding exclusively. Because we are specialists, Drawalloy stainless steel welding wire is produced to strictly controlled specifications to provide the right chemistry, finish and temper for the finest quality weld metal and smoother operation in your automatic or semi-automatic equipment. Drawalloy stainless wires are available in all popular grades as well as 2¼ Cr, 1 Mo; 1¼ Cr, ½ Mo.

Why not discuss your stainless welding wire needs with your Drawalloy Distributor or Representative . . . a man with the products and knowledge to help you. Bulletin 355 DC provides complete information on every grade of Drawalloy wire. Write to: Drawalloy Corporation, Lincoln Highway West at Alloy Street, York 13, Penna.

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# PERSONNEL

## Branch Joins Wall Colmonoy

Appointment of E. M. Branch as engineering representative has been announced by R. L. Peaslee, vice-president and general manager of the Stainless Processing Division of Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich. Mr. Branch has been assigned to the Montebello, Calif. plant.

## Blaha Joins Pittsburgh Coke and Chemical

Walter J. Blaha has joined the Chemical Plant Engineering Department of Pittsburgh Coke & Chemical Co., according to a company announcement.

Mr. Blaha was formerly a maintenance engineer at the Baltimore refinery of Esso Standard Oil Co., having also served as an inspection engineer and construction planner.

A 1952 graduate of the University of Maryland, Mr. Blaha holds the B.S. degree in chemical engineering. He is a member of the AMERICAN WELDING SOCIETY and the Society for Nondestructive Testing.

## Madden Named by Electronic Welding

Kenneth L. Madden is the new plant manager at Electronic Welding Co., Burbank, Calif., according to an announcement from Ray Koepenick, president. Mr. Madden comes to Electronic Welding from Seattle where he was a welding engineer in the Manufacturing Research Department at Boeing and factory superintendent of Sweeden Freezer Manufacturing Co. He brings a number of years of experience, including that of a journeyman welder, to the position. His duties will include direct supervision of all plant operations and production in Electronic Welding's commercial and military contract fabrication program.

Mr. Madden is a member of the AMERICAN WELDING SOCIETY and the Society of Professional Engineers.

## Ehlers Named by Wall Colmonoy

Appointment of Ralph H. Ehlers as engineering representative for the company's Morrisville, Pa. plant has been announced by R. L. Peaslee, vice-president for the Stainless Processing Division of Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich.

In his new position, Mr. Ehlers will be responsible for providing design, development and application engineering assistance to users and potential users of high-temperature brazed assemblies in the eastern seaboard area.

## Donnelly Appointed by All-State

Appointment of John F. Donnelly as director of technical sales training of All-State Welding Alloys Co., Inc., White Plains, N. Y., has been announced by T. D. Nast, president.

The director joined the firm in October of this year. He is to departmentalize the training activities heretofore assigned to the division sales and service managers. Scope of this program parallels the company's expanding lines of alloys and fluxes for welding, brazing, soldering, tinning and cutting. His duties will include technical training of the service personnel of some 750 All-State distributors throughout the country.

Previously, Mr. Donnelly was process representative of Air Reduction Sales Co.; and supervisor of welding instruction and production, Eastern Aircraft Division of General Motors. He holds seven Army and Navy welding certifications and is a member of the AMERICAN WELDING SOCIETY.

Kenneth L. Madden

John F. Donnelly

## OBITUARY

### Horace V. Cleggett

Horace V. Cleggett died of a heart attack on October 11th at the Genesee Hospital in Rochester, N. Y. He was 52.

Born in East Rochester, Mr. Cleggett was employed in welding capacities by the Morley Machinery Corp. for the last 28 years. An active member of the AMERICAN WELDING SOCIETY, Mr. Cleggett had been an Executive Committee member of the Rochester Section for the past three years.

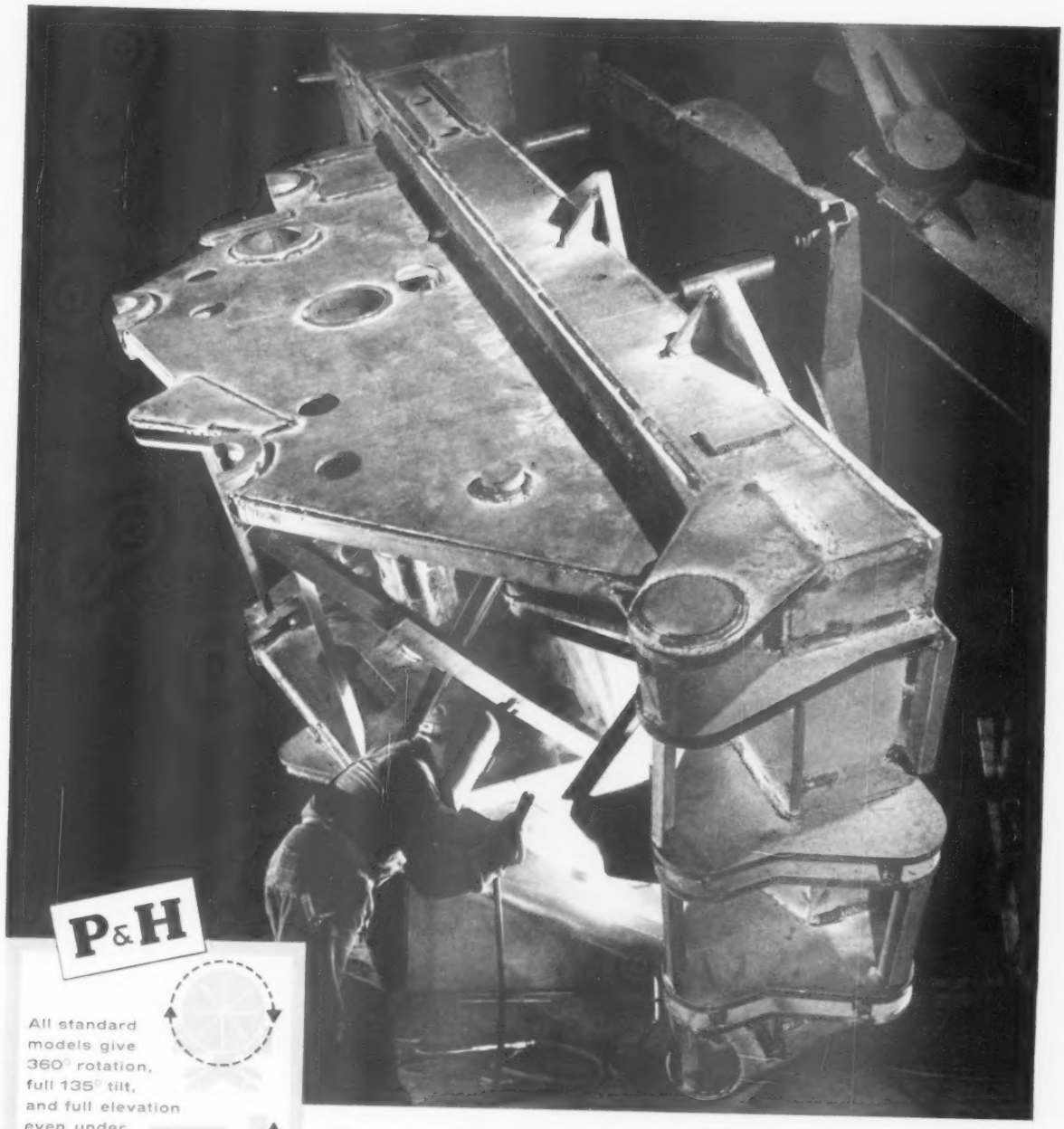
### James H. Critchett

James H. Critchett formerly of Douglaston, L. I., a retired vice-president of several divisions of Union Carbide Corp., died on Dec. 18, 1957 at his home in Orleans, Mass.

Mr. Critchett was born in Watertown, Mass. He attended Massachusetts Institute of Technology, receiving the degree of B.S. from that institution in 1909.

Mr. Critchett joined the Union Carbide organization in 1914 on the metallurgical staff of two Corporation divisions in Niagara Falls, N. Y. Later he moved to New York as part of the Corporation's research organization, subsequently coordinating the activities of the research organization at Niagara Falls with those of the manufacturing and sales divisions. He became a vice-president of Electro Metallurgical Company in 1939 and of several other divisions in 1944, which positions he held when he retired.

During World War II Mr. Critchett was a member of a number of government metallurgical committees of the War Production Board and the National Academy of Science. He was also a member of the AMERICAN WELDING SOCIETY, Theta Delta Chi, Electro Chemical Society, American Foundrymen's Association, American Society for Testing Materials, American Iron and Steel Institute and was on the executive board of the Welding Research Committee of The Engineering Foundation.



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All standard models give 360° rotation, full 135° tilt, and full elevation even under capacity loads

# Your **biggest** saving in welding is in weldment **handling**

P&H Welding Positioners often cut costs up to 43% by making weldment handling easier.

They raise, rotate, and tilt weldments up to 100,000 pounds, completely freeing operators from the time-consuming, hazardous job of repositioning weldments on the floor.

RESULT: Increased production, less operator fatigue, metal flows more readily, pools more evenly to produce cleaner, stronger welds — because all welding is done in the natural *downhand* position.

For more information about how these useful machines can save you money, write to Department 310U, Harnischfeger Corp., Milwaukee 46, Wis.

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P&H WELDERS • ELECTRODES • POSITIONERS
MILWAUKEE 46, WISCONSIN

For more details, circle No. 22 on Reader Information Card

# NEW LITERATURE

## Copper-Alloy Bulletin

Ampco Metal, Inc., Milwaukee 46, Wis., announces the availability of their Fourth Quarter 1957 issue of "Ampco Welding News." Included in the 4-page bulletin are articles describing the use of "Ampco-Trode 10" in the rebuilding of a silicon-bronze turbine runner and the reclamation of a cast-iron vertical lathe spindle with "Ampco-Trode" wires.

For your free copy, circle No. 23 on Reader Information Card.

## Gas-Welding Catalog

Modern Engineering Co., 3409 Pine Blvd., St. Louis 3, Mo., manufacturer of "Meco" oxyacetylene welding and cutting equipment, announces its revised, 36-page, 1958 welding equipment catalog, No. 160, covering recommended applications of its line of oxyacetylene welding and cutting torches, air-acetylene torches, machine cutting torches, welding regulators, industrial regulators, pressure gauges, tank couplings, adaptors, hose connections and safety instruction manual.

For your free copy, circle No. 24 on Reader Information Card.

## Welding Equipment Catalog

The Big 3 Welding Equipment Co., P.O. Box 3047, Houston 1, Tex., has issued a 76-page catalog containing illustrations and descriptions of electric and gas welding equipment. Electric and pneumatic tools are also included.

For your free copy, circle No. 68 on Reader Information Card.

## Presses

An 8-page bulletin, AFP-101, on their complete line of high-speed precision Flexopresses, both "C" type and straight side, is now available from the Precision Welder & Flexopress Corp., 3520 Ibsen, Cincinnati, Ohio. Included are specifications on "C" type from 15 to 75 ton and on straight side from 75 to 200 ton. Explanation is given of the precision ball-bearing ram raceways, referred to as "the first major advance in press construction in 20 years." A complete description is given of Flexopress features, including illustrations of all machines and examples of special tooling.

For your free copy, circle No. 69 on Reader Information Card.

## Soldering Fixtures

Technion bulletin No. 107, issued by Duramic Products Div., Technion Design & Mfg. Co., Inc., 262-72 Mott St., New York 12, N. Y., describes automatic dip soldering of printed circuit boards through the use of ceramic dip-soldering fixtures, made from a heat-resistant product called M 120-F ceramic.

The manufacturer states that Sur-Braze M 120-F ceramic is suitable for use at temperatures at 1065° C and will reportedly handle fixturing of boards up to 12 in. wide.

For your free copy, circle No. 25 on Reader Information Card.

## Blast-Cleaning Catalog

The Wheelabrator Corporation, 1332 S. Byrkit St., Mishawaka, Ind., announces a new 32-page illustrated catalog No. 951-D, covering the company's entire line of airless blast cleaning machines as well as wet blast, air blast and dust control equipment. Also included are cast steel shot and grit abrasives, sandcutters and core rod straighteners.

Also listed is the new line of Wheelabrator "Super Tumblasts," a heavy-duty, high-efficiency batch-type centrifugal blast cleaning machine, available in three sizes.

The new catalog also contains reference to specific literature covering each of the individual pieces of equipment.

For your free copy, circle No. 26 on Reader Information Card.

## Induction-Heater Bulletin

Construction and design features of high-frequency induction heaters and induction melting furnaces are described in bulletin 12B6430B released by Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

Available in output ratings from 10 to 100 kw, the self-contained induction heater is being used in many industries for rapid soldering, annealing, melting, brazing, hardening and forging operations.

Job-designed work coils and work handling equipment for use in connection with Allis-Chalmers induction heaters are also described and portrayed in the bulletin.

For your free copy, circle No. 27 on Reader Information Card.

## Submerged-Arc Welding Guide

A new 4-page folder contains information for individuals using submerged-arc welding on stainless or low-alloy steels. This booklet, issued by Arcos Corp., 1500 S. 50th St., Philadelphia, Pa., pictorially demonstrates the effect of varying welding speed, current, voltage or flux burden, and discusses fringe influences of the various observable results. Text also lists color coding of Arcosite fluxes for submerged-arc welding, the alloys to be welded with each, and the approximate composition of the weld deposit produced.

For your free copy, circle No. 28 on Reader Information Card.

## Copper-Alloy Reference

A revised edition of "Corrosion Resistance of Copper and Copper Alloys," 32-page reference booklet, is announced by the American Brass Co., Waterbury 20, Conn. Continuous laboratory research and field study of the nature of corrosive attack on these metals has been reportedly conducted for a period of 31 years by the company's technical staff. In the edition, Publication B-36R, latest findings are incorporated in the text of Part I, "Theory of Corrosion and Types of Corrosive Attack."

Included is a tabulation indicating the relative corrosion resistance of the principal types of copper and copper base alloys when in contact with 186 different corroding agents.

For your free copy, circle No. 29 on Reader Information Card.

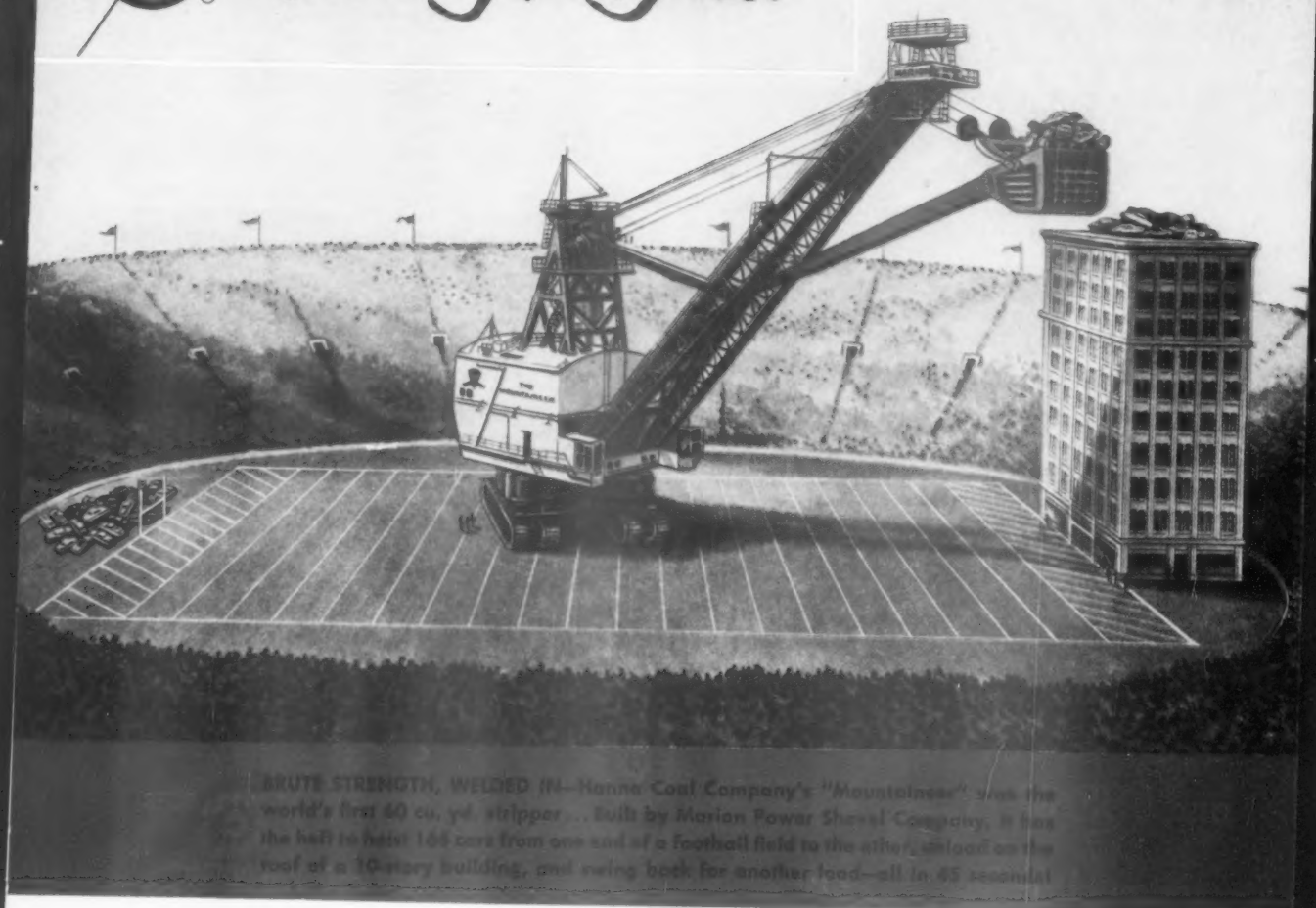
## Welding Supply Catalog

A new 48-page catalog, Form ADC 848B, on supplies and accessories for gas and arc welding is now available from Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y.

Presented in this catalog, which contains over 100 illustrations, is information on ferrous and nonferrous welding rods for oxyacetylene and inert-gas welding; welding and brazing fluxes and their applications; aluminum welding fluxes; silver-brazing alloys; brazing alloys; protective equipment including goggles, glare protection spectacles, cap and goggle combinations, welding helmets and face shields, hard hats, headgear and pocket shields; leather welding gloves; electrode holders and cable connectors; weld cleaning tools; twin and single line hoses; and many other items.

For your free copy, circle No. 30 on Reader Information Card.

Welding Progress



BRUTE STRENGTH, WELDED IN—Hanna Coal Company's "Mountaineer" was the world's first 60 cu. yd. stripper ... built by Marion Power Shovel Company. It has the heft to heist 165 cars from one end of a football field to the other, unload on the roof of a 10-story building, and swing back for another load—all in 45 seconds!

# Murex® Electrodes Help Build Muscles Like This!

Much of the brawn of this 5,500,000 lb. mining giant that continuously scoops 90 tons of mountain without tiring, was knitted with Metal & Thermit arc welding electrodes.

Speedex HTS, and Types HTS-18 and DM electrodes were used for *all* manual welds of the main frame structures, boom and gantry ... Hardex 45 was used to hard surface the boom socket ears to resist impact and wear from the boom. The Mountaineer's round-the-clock performance since January, 1956, has led to the construction of four similar machines, all identically "muscle-powered" with M&T electrodes.

Selecting the right electrode for any of its line of excavators is no problem for Marion. Metal & Thermit's complete line for all welding applications can be applied to any of Marion's machines for sound, reliable, low-cost welds.

Whether you join thin sheet or heavy sections ...fabricate or repair structures of special, mild or low alloy steels or other metals, there is a large selection from M & T's MUREX line of mild steel, iron powder and hard-surfacing electrodes to meet your requirements. Write for your copy of our helpful Electrode Selector...an easy reference for selection of the correct electrode for any application.

METAL & THERMIT CORPORATION

GENERAL OFFICES: RAHWAY, NEW JERSEY

For more details, circle No. 31 on Reader Information Card

# REVIEWS
OF NEW BOOKS

## Engineer's Handbook

*Fogle's Engineer's Handbook*, 8½ by 11 in. Hard paper-back cover, 1958 Edition. Price $15.00. William Fogle, 2412 N. Beachwood Drive, Box 2322, Station 28, Los Angeles 28, Calif.

This handbook for engineers contains calculations, design and details worked out to finality. Suitable as a reference in the shop or field during fabrication, construction or erection.

## Structural Design

*Structural Design in Metals* by Clifford D. Williams, chief engineer of Patchen and Zimmerman, and Ernest C. Harris, chairman, Department of Civil Engineering, Penn College. Clothbound book. Second edition. Price $8.00. 655 pages. The Ronald Press Co., 15 E. 26th St., New York 10, N. Y.

The second edition of *Structural Design in Metals* continues to provide the material for a coordinated first course in design at the junior-session level, following the mechanics and strength of materials courses. It has been revised to incorporate new materials and illustrative examples that reflect the latest specification and design methods.

Chapter 3 is devoted to welding: basic processes and phenomena. Other subjects include riveting, selection of sections, connections, plate girders, trusses, bearings, light gage structural members, fatigue of structural members and rigid frames.

## Engineering Structures

*Brittle Behavior of Engineering Structures* by Earl R. Parker, professor of Metallurgy and chairman, Division of Mineral Technology, University of California, Berkeley. Prepared for the Ship Structure Committee under the general direction of the Committee on Ship Steel, National Academy of Sciences—National Research Council. Clothbound book. Price $6.00. 323 pages. John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y.

The book summarizes the available information on the brittle behavior of steel in engineering structures. It contains a discussion of the theories and mechanism of failure, a review of test methods used for evaluating relative brittleness, interpretations and summaries of test results, a discussion of the effects on welding composition variations on notch toughness, and a report of service failures.

It also contains a survey of the fundamental properties and fracture theories.

## Arc-Welding Lessons

*Arc Welding Lessons for School and Farm Shop*, by Harold L. Kugler, 2nd Edition. Price $1.00 in U.S.A., postage prepaid, $1.50 elsewhere. 343 pages. Bound in hard cover with simulated leather and gold embossing. Published by the James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

Several chapters in the revised edition have been rewritten and the entire text has been reviewed for the purpose of updating. The original paging of the book and the chapter sequence remain unchanged so that both editions may be used together in a class without confusion.

The lessons are contained in two sections, one of 8 informational lessons and one of 17 operational lessons. Each lesson contains information for study exercises, key points, materials used and review questions. Illustrations show details, both with drawings and photographs. Tables, charts, reference data, an index and projects are also included.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Z.R.C. is a free flowing cold galvanizing compound consisting of 95% pure ZINC. Apply by brush or spray gun to welds and galvanized surfaces that have been burned or damaged by abrasion. Z.R.C. will combine readily with existent galvanizing to produce a complete rustproof bond.

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| No. 2 | Brazing Flux |
| No. 4 | "Braz-Cast" Flux for bronze welding cast iron |
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Man experienced in sale of welding machines required by Metal & Thermit Corporation to supervise and assist nationwide sales organization in promoting entirely new line of machines. Must have administrative ability, marketing experience, knowledge of sales promotion, and be willing to travel. Attractive salary plus generous company benefits. Write, outlining previous experience and salary requirements. All replies held confidential. Send replies to: **Employee Relations Department, Metal & Thermit Corporation, Rahway, New Jersey.**

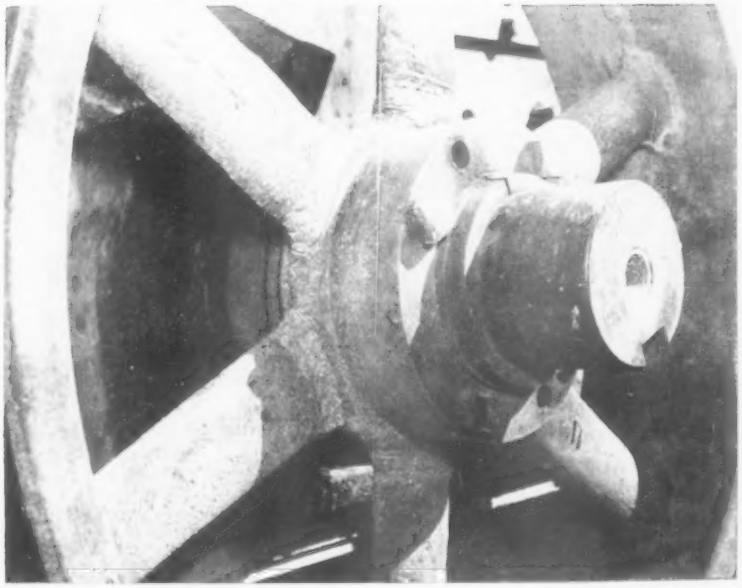
Plant, Research Laboratories and World Headquarters

BETTER ORIGINAL FASTER
Low Temperature EUTECTIC WELDING ALLOYS
STRONGER WELDS

# EUTECTIC Welding News

PUBLISHED BY EUTECTIC WELDING ALLOYS CORPORATION, 40-40 172 STREET, FLUSHING 58, NEW YORK, N. Y.

## WHEN THESE SPOKES CRACKED THIS ROCK CRUSHER STOPPED



*(Cast iron pully wheel, completely disrupted production . . . repaired in under 24 hours with XYRON 2-24.)*

Five of the six spokes on this cast iron pully wheel cracked at the hub, completely shutting down a Northwestern rock crusher installation. Manufacture, delivery and installation of a new pully wheel would take over 3 weeks, with a resultant loss in production.

Company engineers agreed that spokes could be repaired if welding temperatures could be kept low, and preheating eliminated. They realized most failures in welding cast iron are attributable to high heat input and result in cracking.

The local "Eutectic" Technical Representative was called in and recommended Veeing out the cracks with Eutec ChamferTrode, then repairing them with Xyron 2-24 (AC-DC)... a "Low Temperature Welding Alloy."

"Eutectic" is the inventor and sole maufacturer of "Low Temperature Welding Alloys."® Over 350 Technical Representatives from coast to coast are only a phone call away. They provide immediate consultation service and practical advice on any job—anywhere.

Eutec ChamferTrode (DC Straight) can chamfer or gouge out all metals without the use of oxygen. Its special exothermic coating concentrates the force of the arc right at the point of application. The arc blasts unwanted metal from its path, leaving an ideal surface for subsequent operations.

Xyron 2-24(AC-DC) is a patented cast iron electrode for "cold" arc welding, and is designed for repairing long cracks and defects. "Frigid Arc" coating allows greater ease of application at lower amperages.

The lower welding amperages possible with Xyron 2-24(AC-DC), and its ability to do the job without preheating avoids cracking and embrittlement and encountered often with conventional high heat welding materials. All of this permitted the quick, inexpensive complete repair of the pully wheel with such speed that only one shift was lost. When the pully wheel was restored to service, it operated perfectly...well within operational tolerances.

## EUTECROD 1600 PRODUCES ROUND CLEAR NOTES

A world renowned manufacturer of brass wind instruments used this Eutectic "Low Temperature Welding Alloy"® to solve a long standing problem. How to reduce the percentage of rejects caused by joint failures, distortion, pinholes, discoloration and visible blemishes . . . all due to high welding temperatures.

A "Eutectic" Technical Representative recommended EutecRod 1600 be used to join component parts of clarinets, French horns, trumpets, trombones and saxophones. EutecRod 1600, a universal copper, brass and bronze alloy is an outstanding "brazing" type alloy; ideal for short, thin joints, far superior to conventional brazing alloys. Ultimate tensile strength: 55,000 psi. Since it does not require fusion of the surface of the base metal, EutecRod 1600 may be applied at very lowest temperatures.

The manufacturer now reports perfect color match and elimination of high heat warping, distortion and pinholing. Rejects have been drastically reduced, production costs cut.

**FREE — JUST OFF THE PRESS —**

NEW 1958 180 page pocket **WELDING DATA BOOK**
Complete guide to modern welding techniques

**EUTECTIC'S TECHNICAL INFORMATION DIGEST HELPS YOU MAKE BETTER, FASTER WELDS**

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**AUTOMOTIVE WELDING ISSUE (TIS 2822)**
Latest welding techniques to do better repair jobs on your automotive equipment. Everything from body work to motor blocks.

**TOOL & DIE ISSUE (TIS 2831)**
Costly tools can be fabricated inexpensively in any shop with welding. Expensive dies, whether cast iron, cast steel or kirksite can be repaired quickly. This manual tells how.

**CONSTRUCTION MAINTENANCE WELDING ISSUE (TIS 2832)**
Keeping equipment moving is essential to any builder. Learn new techniques that assure longest, most efficient service life from construction machinery and tools.

"EUTECTIC" WELDING HEADLINES • TIME-MONEY-MACHINERY SAVERS

# NEW PRODUCTS

## Cutting Attachment

A new accessory for use in making simultaneous parallel cuts with one Airco Style 4700 machine cutting torch is announced by Air Reduction Sales Co., a Division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y.

The fully-adjustable Duplex Tip Holder may be set to cut strips of any

width from 1¼ to 12 in., in plate thicknesses up to 3 in. Tip separation is easily set without tools, and without changing torch height. The minimum tip spacing of the new holder is less than that of the fixed holders now available. Versatility of the unit is such that it replaces Airco's entire line of fixed duplex holders.

According to the manufacturer, such operations as plate ripping and the simultaneous cutting of small pieces or inside and outside circles are reportedly facilitated by use of the holder. It will accommodate acetylene, propane or natural-gas tips.

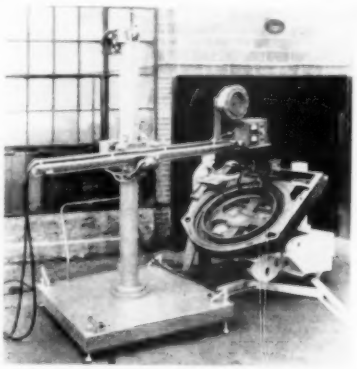
Although designed for machine cutting, this device can also be used in the Airco Styles 3000 and 9000 hand cutting torches for particular applications.

For more details, circle No. 35 on Reader Information Card.

## Medium-Sized Positioners

The Lewis Welding & Engineering Corp., 78 Interstate St., Bedford, Ohio, announces the development and availability of a new "Bantam" series of automatic welding head manipulators. Designed to position and pilot standard automatic welding heads with extreme accuracy, these mobile machines are recommended for shops requiring versatile equipment for medium-size fabrications (such as subassemblies), small production runs or special jobs. "Bantam" manipulators are intended primarily for application with work-holding positioners or turning fixtures. They reportedly weld straight seams up to 8 ft long and provide 8 ft of underboom clearance.

According to Lewis, features of the new Lewis "Bantam" manipulator include 360-deg rotation of boom, infinitely variable welding speeds up to 87 ipm and a base equipped with integral wheels for ready mobility and



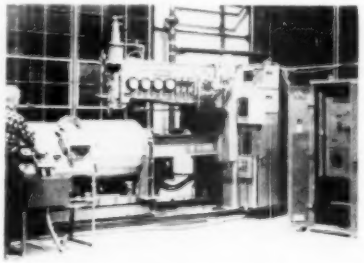
leveling screws for positive positioning. This manipulator is also said to operate with consistent accuracy while handling boom-tip loads up to 250 lb.

For more details, circle No. 36 on Reader Information Card.

## Automatic Resistance Welding

According to a recent announcement, National Electric Welding Machine Co. and the General Electric Co. joined forces to produce the nation's first automatically-programmed resistance-welding machine.

Now in operation at General Electric's Small Aircraft Engine Department,



Everett, Mass., the machine is used to weld tabs on cylindrical liners for jet engines. Its utilization has reportedly resulted in an 85% reduction in assembly and weld time and is expected to save about $26,000 annually in the manufacture of jet engines.

This new degree of automation has been made possible by the application of two General Electric products—numerical positioning control and resistance-welding control—to a National Electric welding machine.

For more details, circle No. 37 on Reader Information Card.

## Semiautomatic Hard-Surfacing Unit

Alloy Rods Co., York, Pa., made its entry into the equipment field recently with the introduction of a wire feed unit for semiautomatic open-arc hard surfacing. The new semiautomatic welder will be sold under the trade name "Wear-O-Matic" wire feed unit. For use with the welder, the company also announced a new line of Wear-O-Matic open-arc $\frac{7}{64}$-in. diam hard-surfacing wires.

According to Alloy Rods, the Wear-O-Matic wire feed unit provides for the user quicker, easier setup; faster wire change-over and a greater degree of portability.

The Wear-O-Matic wire feed unit is

designed to use Wear-O-Matic wires packaged in "Payoffpaks." Thus, the wire supply is separate from the unit which weighs 70 lb.

Since the wire is drawn directly from the Payoffpak, there are no wire coils to untie and retie when changing types of wire. Threading the wire through the welder is reportedly easier than on units using coiled wire.

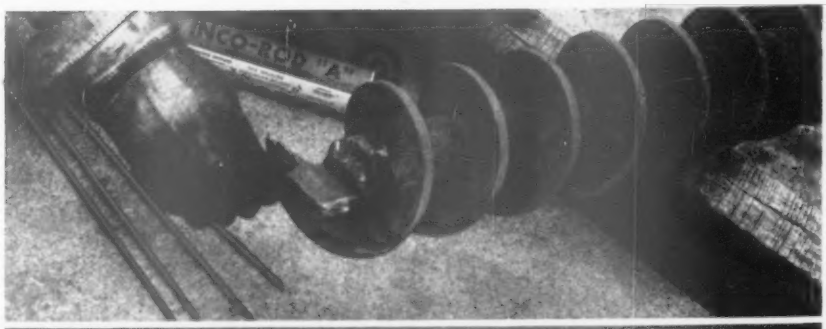
The Wear-O-Matic wire feed unit will operate from nearly any d-c power source and only two electrical connections are required.

For more details, circle No. 38 on Reader Information Card.

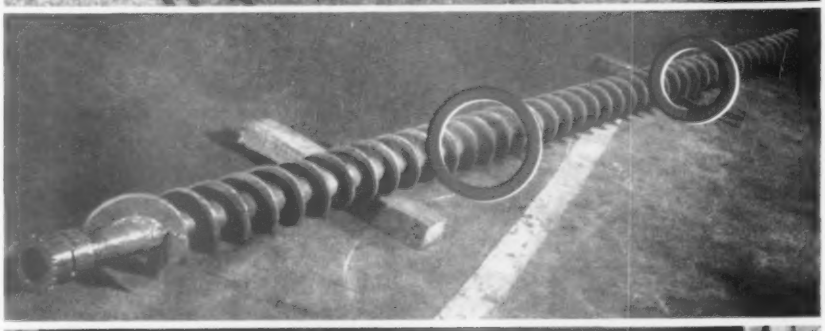
## Wear Resistant Shapes

Industrial Overlay Metals, Inc., Eaton, Ohio, manufacturers of Bergstrom alloys and products, announce the addition of four new products to their pres-

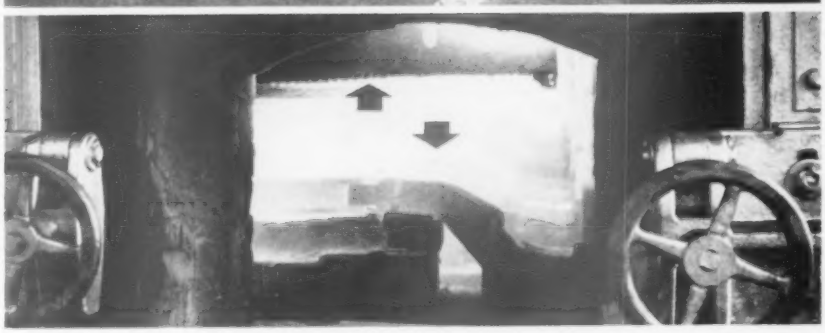
*Inco Rod "A" electrode triples life of problem joint...*




*in heat resistant alloy screw conveyor...*



*subject to 1725°F to 1800°F temperatures.*



# Now—one electrode . . . Inco Rod "A" handles most problem joints

*...welds most dissimilar alloys as well*

Lap welded joints in the Duraloy screw conveyor (above) never used to last more than four months.

Cyclical heating and cooling caused the welds to crack and break.

Engineers at The Chicago Heights plant of Alco Products Inc. decided to try Inco Rod "A"* electrode. Today they report these welds are still going strong after a *year's service*. No preheat is used. And the entire welding job takes only three hours.

*If you want strong, sound, ductile welds in problem joints* try Inco Rod "A" electrode. No special equipment or training is needed.

You can also use this versatile Inco electrode to get X-ray quality welds between many dissimilar alloys ...between ferritic and austenitic stainless steels...between low alloy and mild steels...between high-nickel and other alloys.

**Helpful booklet—"Inco Rod 'A'"—Free!**

Contents include case histories on problem welds solved with Inco Rod "A" electrode and results from test data compiled on 23 dissimilar alloy combinations. Send for your copy today.

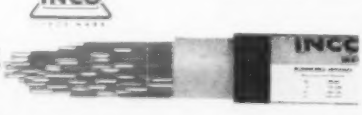
*Registered trademark

**THE INTERNATIONAL NICKEL COMPANY, INC.**

67 Wall Street — New York 5, N. Y.

INCO

## INCO WELDING PRODUCTS




**ELECTRODES • WIRES • FLUXES**

For more details, circle No. 39 on Reader Information Card

Close laboratory control and use of virgin metals assure uniformly high quality in foot after foot of this new, versatile rod for . . .

1. Brazing and braze-welding steel, cast iron, malleable iron, copper and its alloys with the oxy-acetylene process.
2. Building up bearing, wear- and corrosion-resistant surfaces on steel and cast-iron parts.

Smooth, dense, free-flowing deposit has excellent tinning action. You get welds with up to 60,000 psi. ultimate tensile strength on high-strength manganese-bronze base plates — and up to 50,000 psi on steel base plates. Overlay deposit hardness on steel or cast iron is 80-110 BHN (500 kg.)

Order Ampco-Brāz #2 from your nearby Ampco distributor. He has it in 1/16", 3/32", 1/8", 3/16", 1/4", 5/16", and 3/8" diameters.

Send coupon for free Bulletin W-17.

*Sole producer of genuine Ampco Metal*

AMPCO

**AMPCO METAL, INC.**
Dept. WJ-2, Milwaukee 46, Wisconsin
West Coast Plant: BURBANK, CALIFORNIA

**AMPCO-BRāZ FLUX #2**
New — for general brazing, and cast-iron welding and brazing. Cuts costs, saves time. Has many advantages:
No fluorides present.
Excellent wetability.
Depresses filler-metal bubbling and fuming.
Non-fuming.
Deep-penetrating.
Protects against excessive oxidation.
Available in 1-lb. can from your Ampco distributor. Order today.

Tear out coupon and mail today!

AMPCO METAL, INC.
Dept. WJ-2, Milwaukee 46, Wis.

Send me Bulletin W-17 for further information on Ampco-Brāz #2 and other Ampco electrodes.

Name.....
Company.....
Address.....
City..... Zone..... State.....

W-147

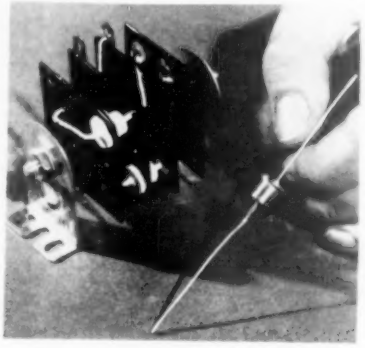
For more details, circle No. 40 on Reader Information Card


cut line. Various sizes in rectangular and square shapes are now available in "Dimaloy Abrasion Strips," containing 60-80% tungsten carbide shapes and particles. "Mangaloy Multi-Service Castings," 11-14% heat-treated manganese steel, are recommended as replaceable hammer mill tips. "Mangaloy Cast to Shape Applicator Bars" in three standard shapes and "Mangaloy Tooth Repointing Bars" in five standard shapes have also been introduced to the Bergstrom line.

For more details, circle No. 41 on Reader Information Card.

## Silicon Rectifiers

Three new silicon-power-rectifier diodes (Types 305, 320 and 321) are now available from the Westinghouse Electric Corp., Pittsburgh 30, Pa.



Designed for all types of power applications, these new hermetically-sealed silicon-rectifying cells reportedly provide d-c forward currents up to 1.6 amp with a maximum peak inverse voltage up to 800 v.

According to the manufacturer, maximum forward voltage drop at one amp and 125° C case temperature is 1.3 v. The peak leakage current at the same case temperature will not exceed 1.5 ma. Maximum operating frequency is 50 kc. Operating junction temperature is 175° C.

All three cells are said to be available in complete rectifier-bridge assemblies.

For more details, circle No. 42 on Reader Information Card.


AWS
WELDING SHOW
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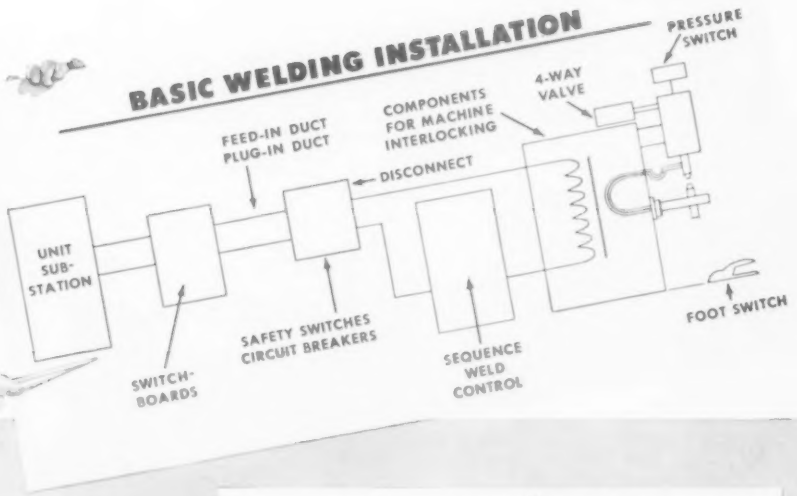
St. Louis, Missouri




# Here's the Easy Way

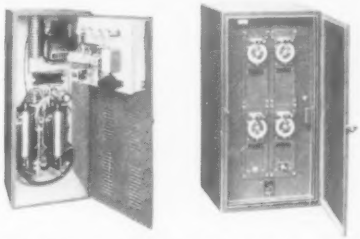
## TO A BETTER WELDING INSTALLATION

• Whether you start from scratch or expand an existing operation, your Square D Field Engineer has two important things to offer to make your job easier.

First, he has the background which enables him to offer sound counsel at the planning stage. Second, he is backed by a complete line of performance-proven electrical equipment with which to put practical planning into action.

Field Engineers are available through Square D branch offices in all principal United States cities—and in Canada, Mexico and England. Backing up these engineers are the design and manufacturing facilities of 14 strategically located Square D factories and the localized services of a nation-wide network of authorized electrical distributors.

### SQUARE D DOES THE *Complete* JOB!



ELECTRONIC and MAGNETIC WELDER CONTROL

SUBSTATIONS

SWITCHBOARDS

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SAFETY SWITCHES

LIMIT SWITCHES

PRESSURE SWITCHES

4-WAY VALVES

PUSHBUTTONS

SELECTOR SWITCHES

CONTROL RELAYS

FOOT SWITCHES

PILOT LIGHTS

**NOW...EC&M PRODUCTS ARE A PART OF THE SQUARE D LINE**

# SQUARE D COMPANY

For more details, circle No. 43 on Reader Information Card

## Single-Stage Regulators

According to Air Reduction Sales Co., Division of Air Reduction Co. Inc., 150 E. 42nd St., New York 17, N. Y., their new single-stage, inverse-type regulators embody a number of modifications which make them a complete departure from previous types.

Each of the 8100 Series regulators, whether for oxygen, acetylene, hydrogen, nitrogen, argon, helium or carbon dioxide, is designed to provide a substantially higher delivery rate, and to maintain a more constant delivery pressure. These regulators are said to allow low cylinder pressure end points; therefore the gas is more completely exhausted from the cylinder, which on a long-term basis means worthwhile economy.

For more details, circle No. 45 on Reader Information Card.

## Furnace-Brazing Compound

A new Nicrobraz "stop-off" material that acts as a parting compound to prevent the brazing of not-to-be-brazed

mating surfaces during furnace-brazing operations is now available from Stainless Processing Division, Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich.

Named "white stop-off," the new parting material is supplied in powder form. In use, it is mixed with a volatile plastic, called Nicrobraz Cement, to facilitate application.

When mixed with Nicrobraz Cement to the proper consistency, it may be applied by brushing, dipping or spraying. Residue following brazing is removed by air-blasting or brushing.

For more details, circle No. 46 on Reader Information Card.

## Regulator and Torch Design

Liquid Carbonic Division of General Dynamics Corp., 3100 S. Kedzie Ave., Chicago 23, Ill., recently announced an alteration in their manufacturing specifications for torches and regulators. Rather than to continue the distribution of equipment constructed of bronze castings and forgings, Liquid Carbonic commissioned a leading manufacturer to produce regulators precision-machined from solid bar stock and equipped with non-igniting seats, a feature which reportedly reduces operational hazards. Smoother maintenance is also reported from the functionally-designed Liquid-weld torches.

For more details, circle No. 47 on Reader Information Card.

## Automation Soldering

Fusion Engineering Co., Cleveland, Ohio, has announced the completion of preliminary tests on an automation soldering process. Fusion Engineering's latest paste type alloys, consisting of pure solder powders combined with special fluxes and neutral binders to form a stable paste, are used together with automatic heating equipment. These pastes are pre-placed in the joint area previous to soldering, using automatic or semiautomatic dispensers. The dispensers are reportedly capable of metering the exact amount of paste up to 0.01 oz of material and are said to deposit this material in dots, stripes or special patterns.

For more details, circle No. 48 on Reader Information Card.

## Stainless-Steel Electrode

Champion Rivet Company, Harvard Ave. & E. 108th St., Cleveland 5, Ohio, announces the availability of a new stainless-steel electrode. Known as Champion 16-8-2, the electrode was developed for welding both Type 347 and 316 material used in the power-piping field applications. According to Champion, it meets the need for an electrode to weld these materials under restraint with freedom from cracking in either weld, zone of fusion or base metal.

For more details, circle No. 49 on Reader Information Card.

NOW . . . MORE CONTINUOUS OPERATION . . . AT LOWER COST!
1833
MANGANAL ®
11%-13½% MANGANESE-NICKEL STEEL
MILL LENGTH HOT ROLLED WEDGE BARS
1834
• 14 to 18 foot bars mean less scrap loss.
• Can be bent hot or cold.
• No defects common to castings.
• LONG LENGTHS FOR BUCKET LIPS, GRIZZLY BARS, ETC.
1835
Plus 5 other sizes
NATIONAL WELDING SUPPLY ASSOCIATION MEMBER
Send for price list and name of nearest distributor
SOLE PRODUCERS
STULZ-SICKLES CO.
PORT AVENUE at JULIA ST. ELIZABETH, NEW JERSEY
For more details, circle No. 44 on Reader Information Card

## Pipe-Beveling Accessory

The H&M Pipe Beveling Machine Co. of Tulsa, Okla., has announced the addition of the new "flexible shaft" to their line of accessory equipment, reportedly made to fit any size in their pipe cutting and beveling machine line.

The flexible shaft is designed to allow complete visibility of the cutting or beveling operation. It is made from a length of flexible tubing, with a crank handle attached to one end of the tubing and the other end attached to the crank pinion on the machine. As the operator turns the crank, the ring gear is put in motion, and the torch begins its revolution around the pipe.

For more details, circle No. 52 on Reader Information Card.

## Hard-Surfacing Plates

Kenplate, an adaptation of Kennametal cemented tungsten carbide, has been announced by Kennametal Inc., Latrobe, Pa.

The new material consists of small hexagonal plates of cemented tungsten carbide assembled in a continuous pattern on an adhesive glass fiber backing to

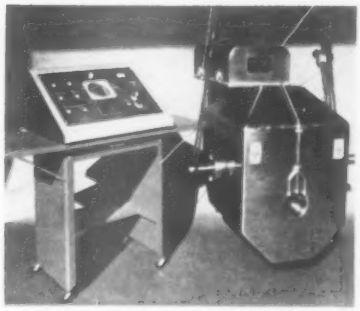
provide flexible sheets or strips for application on flat or curved surfaces. The adhesive backing reportedly holds the small plates in position while they are being bonded by epoxy adhesives, silver solder or conventional brazing materials to provide continuous surfaces that utilize the exceptional wear-resistance properties of hard tungsten carbide.

Two sizes of hexagons, each in three thicknesses are now being made, according to the announcement. They are 0.425 and 0.210 in. across the flats. Thicknesses are 0.040, $\frac{1}{16}$ and $\frac{1}{8}$ in. for 0.210-in. plates, and $\frac{1}{16}$, $\frac{1}{8}$ and $\frac{1}{4}$ in. for 0.425-in. plates. Kenplate is also available in strip form.

For more details, circle No. 53 on Reader Information Card.

## Gamma Radiography

It has been reported that the largest commercially built gamma radiography machine has been shipped by Nuclear Systems, a division of the Budd Co., to Dominion Foundries and Steel, Limited, of Hamilton, Ontario.



The 1060 series Multitron is said to have a capacity of 1000 curies of Cobalt 60, resulting in exposure times comparable to those of 2,000,000-volt X-ray equipment.

The 1060 series Multitron reportedly has a 5000-lb heavily-shielded stainless-steel-clad lead-filled head which serves as both storage and shipping container. Operation is said to be completely safe through a remote console with completely fail-safe electrical controls.

For more details, circle No. 54 on Reader Information Card.

## Work Gloves

The latest work glove introduced by Industrial Glove Division, Riegel Textile Corp., Conover, N. C., features 300 molded little dots per square inch, intended for longer wear and improved grip. The dots are made of plastic and are said to enhance the gripping quality of the gloves.

The "Mighty-Grip" glove is also said

# METALLURGIST

## Stainless Steel Electrodes

A long established manufacturer has an opening for a metallurgist with broad experience in the manufacture and coating of stainless steel electrodes. Salary is open. Location provides ideal suburban living. Please supply detailed background in your reply.

**Box No. 351, THE WELDING JOURNAL, 33 West 39th Street, New York 18, New York.**

**Just You TRY to *Break a***

**THERMO *Spiral***

**TIP CLEANER**

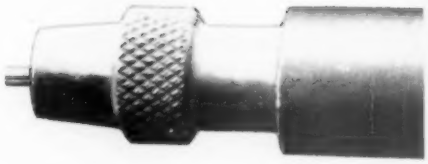
The exclusive, non-breakable advantage of THERMO TIP cleaners didn't just happen—No Sir. This feature resulted after 10 years research, and experience. That's why we say no other type or make can match a THERMO, and the best way to prove that statement is to send for a FREE THERMO Spiral Tip Cleaner and put it to every test—as to its cleaning efficiency and long lasting performances. Yes, just TRY to break it—then you'll know why—

***All progressive Welding Supply dealers Recommend THERMO TIP CLEANERS***

**THERMACOTE *Company***

**1085 DeLacey Ave.**
**PASADENA, CALIFORNIA**

Circle No. 51 on Reader Information Card



# NEW WEST·ING·GUN

## Cuts Welding Costs! Speeds Production!

## GETS EVERYWHERE!

**Hard-to-weld Metals Now Welded Automatically!** There is now a portable hand gun—for gas-shielded welding of aluminum, mild and stainless steels, bronze, copper and magnesium! Moreover, this hand gun has its *own self-contained wire supply!*

It is named the WEST-ING-GUN. It works with any standard DC welding machine. It has *averaged* horizontal fillets of 22 inches-per-minute—with $\frac{1}{16}$" wire! Throughout *extensive* field tests, this WEST-ING-GUN has *doubled men's daily output!*

**OPERATOR FATIGUE "ELIMINATED"!** This WEST-ING-GUN "handles" as easily as pointing your finger, to weld in *any* position—regardless of cramped quarters! Its portability between gun and control—between control and power-source—provides complete working freedom and ease—up scaffolding—atop ladders—all around any type of workpiece. This gun weighs only four pounds—including its full, pound reel of wire! Operators working a steady 30% duty cycle, with WEST-ING-GUNS, say they "feel no fatigue at all"!

**Welding Remote from Power Source!**

20-lb control is readily carried up superstructures! Every shipyard visited, during field-tests, immediately ordered WEST-ING-GUNS!

**Time Saved in Tight Quarters!**

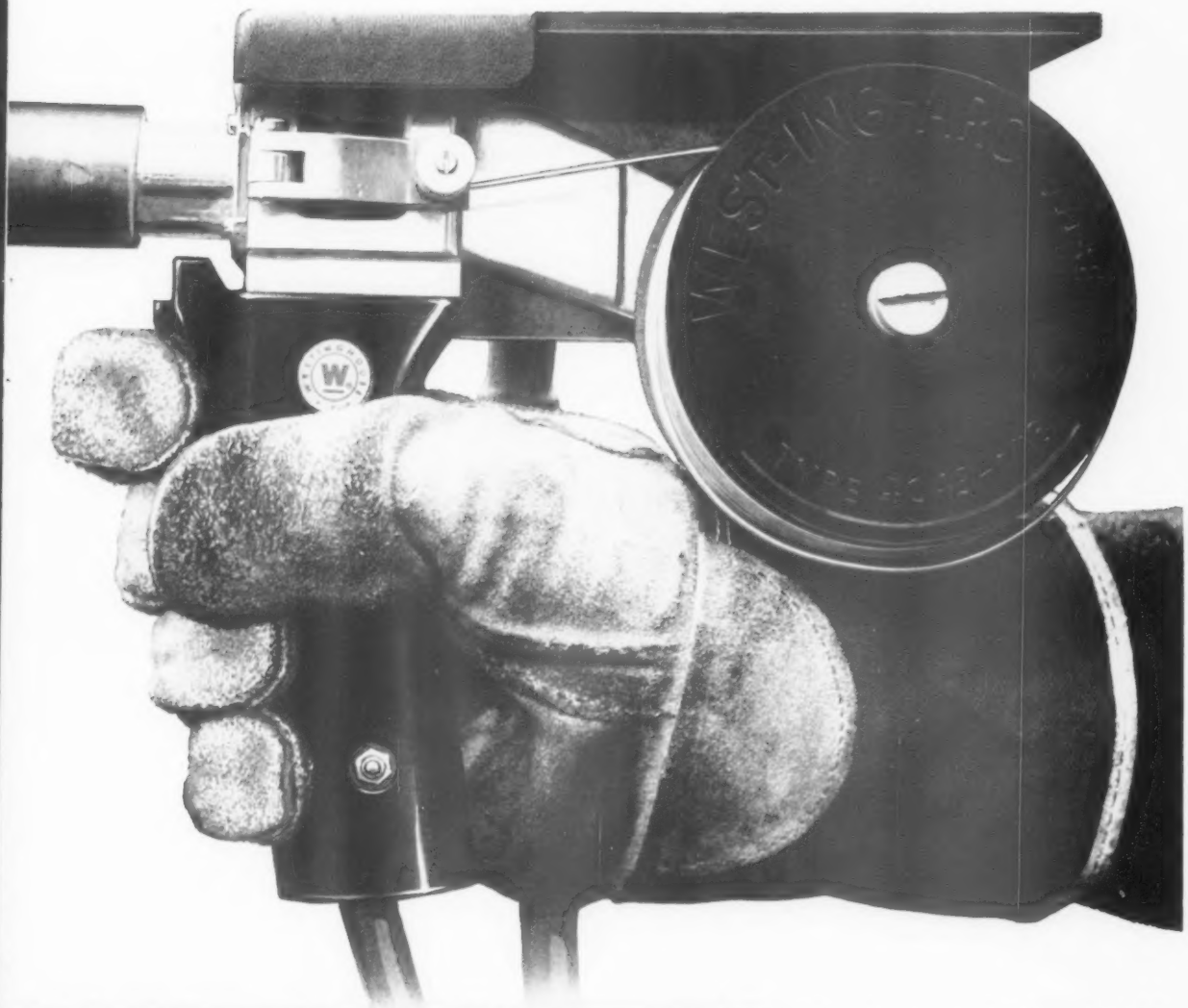
Weld wherever you please! Power and shielding gas are in a single-hose assembly. This permits access to heretofore "impossible" locations!

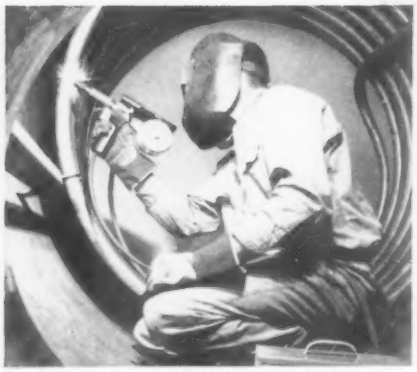
**New Welding Speed on Big Units!**

You can take the gun wherever you want to weld! The control stays with the machine! One man can now do the work that used to require two!

*Watch Westinghouse for New Developments*

For more details, circle No. 55 on Reader Information Card



**Maintenance Welding Simplified!**

WEST-ING-GUNS and light-weight control units do the job quickly! Invaluable as a time- and cost-saving production tool!

**Aircraft Quality Welds Every Time!**

Difficult welds are readily completed with new ease—in production of aircraft equipment—often weld back into normally inaccessible areas!

*in Welding*

A unique, gear-head replaceable mechanism in the handle drives $\frac{1}{16}$" wire up to 350" per minute (finer wire *twice* as fast)! Wire is "inched" at the touch of a button. The short, 6" travel eliminates wire-feeding problems!

There are WEST-ING-GUNS and the controls available—for any DC welders. The compact, rugged control-unit for each model weighs less than 20 pounds. Virtually *every* welding shop has *countless* applications where WEST-ING-GUNS will save *appreciable* amounts of money!

Avail yourself of the opportunity to see what this new production tool can do for you! Contact your nearest franchised Westinghouse Welding Distributor; or write to the Westinghouse Welding Laboratories, Box 2025-A, Buffalo 25, New York.

J-22199

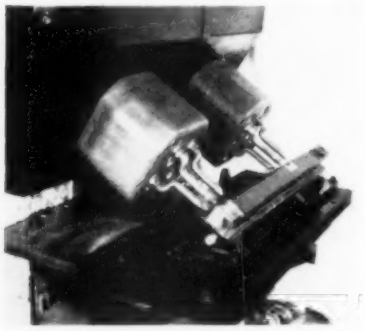
For more details, circle No. 55 on Reader Information Card

to permit rapid evaporation of perspiration.

For more details, circle No. 56 on Reader Information Card.

## Resistance-Welding Guns

Callon Corp. Ltd., 1857 Walker Rd., Windsor, Ontario, announces a new design for use in multi-spot resistance welding. According to the Canadian firm, machine tool quality is achieved by



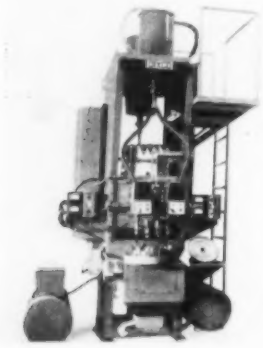
using plastic and fibreglass construction to house the guns and their accessories. Among the advantages reportedly realized are the material improvement of the electrical efficiency due to the absence of all metal in the field and, since the work area is free from all obstructions, more safe work can be done in one machine. Maintenance is said to be reduced to a negligible factor.

For more details, circle No. 57 on Reader Information Card.

## Submerged-Arc Welder

A new submerged-arc welder that reportedly does a job which had previously required two machines has been designed and built by Dix Engineering Co., Inc., Lincoln Park, Mich. Fully automatic except for loading and unloading, the welding machine was developed for an operation in the manufacture of automatic transmissions.

According to the manufacturer, the user of this machine has two models of flywheel-ring gear assemblies to weld. For the first, the operator loads the assembly of a ring gear prepressed to a flywheel stamping into the holding and locating fixture of the machine. Nineteen seconds after the run buttons are pushed, 10 equally spaced submerged-arc spot welds are completed with the part indexed and welded automatically.



When production specifies the second model, flipping a selector switch on the control board will cause the machine to join this assembly with 10 unequally spaced welds. This dual purpose welder is said to process 100 per hr of either assembly at 80% efficiency.

For more details, circle No. 58 on Reader Information Card.

## Nondestructive Testing Kit

Magnaflux Corp., 7300 W. Lawrence Ave., Chicago 31, Ill., has made available a portable fluorescent-penetrant inspection kit for locating cracks, pores, leaks and other defects open to the surface in any solid material. This kit, known as the Zyglo ZA-43, reportedly contains the most sensitive of the Zyglo materials—all in push-button, pressurized spray cans.

Included in the kit's steel carrying case are: pressurized spray cans of cleaner, penetrant and developer; a 100-watt high-intensity "black light"; cleaning cloths; wire brush; and detailed instructions.

For more details, circle No. 59 on Reader Information Card.

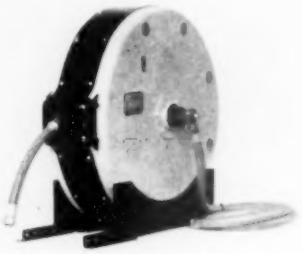
## Portable Grinder

The Nedco Co., 27 Jones Rd., Waltham 54, Mass., announces cushion-type disc supports for depressed center resinoid disks and wheels. These supports are offered in 3 and 4 in. diam and are supplied with $\frac{5}{8}$ in. × 11 thread. Nedco maintains that they will fit practically any grinder, air or electric.

For more details, circle No. 60 on Reader Information Card.

## Industrial Reel

United Specialties, Inc., El Dorado, Ark., announce the addition of the Weldreel Model A-2 unit with a capacity of 50 feet of $\frac{1}{2}$-in. ID single hose. Designed for use with compressed air, industrial gases, liquids and chemicals, the unit features the universal type mounting bracket which reportedly permits easy installation on wall, floor, ceiling or mobile equipment.



Heavy-duty clock-type spring is said to provide automatic retraction into metal housing when hose is not in use. Teflon seals assure leak-proof operation at all normal operating pressures. Hose is locked at any desired length by position action pawl and is released by means of a slight tug on hose.

For more details, circle No. 61 on Reader Information Card.

## Ceramic Cups

According to the manufacturer, a new line of replacement nozzles for all popular makes of inert-gas welding

torches has just been announced by Technical Ceramics and Lava Corp., 85 Fifth Ave., Paterson, N. J.

These nozzles are reportedly manufactured of a superior ceramic to insure longer service and to provide the user with lower initial costs.

For more details, circle No. 62 on Reader Information Card.

# NEW AIRCO SINGLE-STAGE REGULATORS *with*

The newest line of AIRCO Single Stage Regulators includes the 8100 Oxygen Regulator, illustrated above, and the 8102 Acetylene Regulator. Regulators for Hydrogen, Nitrogen, Argon, Helium and $CO_2$ also available in the 8100 series.

- **More constant delivery pressure**
- **Lower end point of gas in cylinder content**
- **Delivery pressure remains close to desired pressure while cylinder pressure decreases**

These new 8100 series single stage regulators are of the inverse type, ideally suited to meet the cutting and welding needs of shipyards, scrap yards, steel mills, industrial plants. Exceptional performance is obtained through the use of a large diaphragm effective area. Exterior ribbing on the forged brass adjusting knob provides an easy grip. Long useful life with simplicity and ease of maintenance make the 8100 series a sound working regulator for all types of welding and cutting.

Ask your Authorized Airco Dealer for complete information, or contact AIRCO direct.

AIRCO — *AT THE FRONTIERS OF welding PROGRESS YOU'LL FIND...*

**AIR REDUCTION SALES COMPANY**

150 East 42nd Street, New York 17, N. Y.
A division of Air Reduction Company, Incorporated
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In Canada — Air Reduction Canada Limited

For more details, circle No. 63 on Reader Information Card


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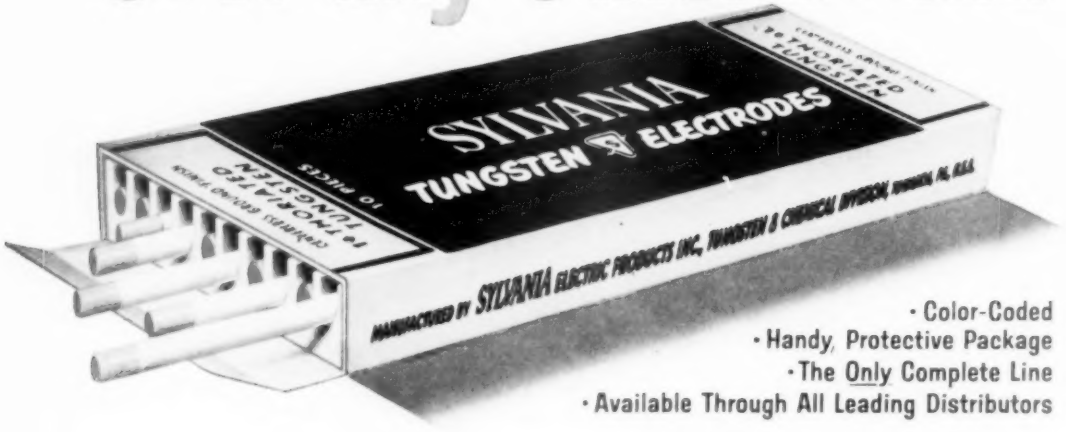


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| 16 | 41 | 66 | 91 | 116 | 141 |
| 17 | 42 | 67 | 92 | 117 | 142 |
| 18 | 43 | 68 | 93 | 118 | 143 |
| 19 | 44 | 69 | 94 | 119 | 144 |
| 20 | 45 | 70 | 95 | 120 | 145 |
| 21 | 46 | 71 | 96 | 121 | 146 |
| 22 | 47 | 72 | 97 | 122 | 147 |
| 23 | 48 | 73 | 98 | 123 | 148 |
| 24 | 49 | 74 | 99 | 124 | 149 |
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# DEVELOPMENT OF FILLER WIRES FOR WELDING SAE 4130, 4140 AND 4340 STEELS

*Best results obtained by using filler wires with composition similar to base material; satisfactory welds also produced, at most strength levels, with dissimilar wires*

BY H. W. MISHLER, R. P. SOPHER AND P. J. RIEPPEL

ABSTRACT. Filler wires were developed for welding high-strength low-alloy aircraft steels by the inert-gas tungsten-arc and inert-gas consumable-electrode processes.

The major factors considered in the evaluation and development work were: (1) weld-metal porosity, (2) weld-metal cracking tendency, (3) heat-treatment response as compared with the base materials, (4) strength of heat-treated weld joint, and (5) weld-metal toughness. Two filler wires were developed for welding each of three steels, SAE 4130, 4140 and 4340. One of each pair of filler wires had a composition similar to the base material, while the other was of dissimilar composition. Sound, crack-free welds, heat treatable to 200,000 psi, were deposited under a high degree of restraint with these filler wires. The best results were obtained by using the filler wires with composition similar to the base material, although satisfactory welds were made at most of the strength levels with the dissimilar filler wires.

## Introduction

The increased use of high-strength low-alloy steels in the production of aircraft components has required the development of coated electrodes and filler wires that will produce welds capable of meeting the service requirements. In many cases, it is advantageous to use the inert-gas tungsten-arc and inert-gas consumable-electrode processes for welding these steels. However, the use of these methods of welding has been hampered by the inadequacy of filler wires that are presently available. Some of the difficulties that are being encountered are porosity, weld-metal cracking and inadequate response to heat treatment. The development of filler wires for welding SAE 4130, 4140 and 4340 steels to overcome these difficulties was undertaken under the sponsorship of the Wright Air Development Center.

This investigation was divided into two phases, which ran concurrently. Phase 1 consisted of an evaluation of available commercial filler wires, and Phase 2 was the development and evaluation of experimental alloy filler wires. The prime target was to obtain two filler wires for welding each of the three steels. One of these filler wires was to have a composition similar to that of the base material while the other was to be of a dissimilar composition.

The evaluation of the commercial wires consisted of first making a series of screening tests. These studies consisted of: (1) restrained joint tests to determine cracking resistance, (2) radiographs of welds to check porosity and (3) heat-treatment tests to determine the response of the weld deposits to standard base-metal heat treatments. Following the screening tests, the tensile and notched-bar properties of the weld deposits were determined. Based on the results of these tests, the experimental wires of Phase 2 were developed.

## Material

The materials used in this investigation consisted of three different base

Table 1—Chemical Compositions and Thicknesses of Base Plate

| *Steel* | *Thickness, in.* | *Chemical Composition, %* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *C* | *Mn* | *P* | *S* | *Si* | *Ni* | *Cr* | *Mo* |
| SAE 4130 | 1/16 to 1/2 | 0.30 | 0.50 | 0.010 | 0.020 | 0.26 | 0.13 | 0.90 | 0.21 |
| SAE 4140 | 1/2 | 0.41 | 0.85 | 0.014 | 0.021 | 0.27 | 0.19 | 0.99 | 0.21 |
| SAE 4340 | 1 | 0.39 | 0.71 | 0.010 | 0.010 | 0.29 | 1.78 | 0.83 | 0.27 |

H. W. Mishler is Principal Welding Engineer, R. P. Sopher is Assistant Chief and P. J. Rieppel is Chief, with the Metals Joining Division, Battelle Memorial Institute, Columbus, Ohio.

This paper was presented in part at the 1958 AWS National Spring Meeting, May 7-11, Buffalo, N. Y.

Table 2—Chemical Compositions and Sources of Supply of Filler Wires

| Filler wire | Type | Chemical composition, % C | Mn | P | S | Si | Ni | Mo | Cr | V |
|---|---|---|---|---|---|---|---|---|---|---|
| SAE 4130 | Commercial wire | 0.29 | 0.53 | 0.009 | 0.015 | 0.29 | ... | 0.22 | 0.97 | ... |
| SAE 4130 A | Experimental | 0.31 | 0.68 | 0.007 | 0.008 | 0.55 | ... | 0.26 | 1.03 | ... |
| SAE 4140 | Fabricated from base material | 0.41 | 0.85 | 0.014 | 0.021 | 0.27 | 0.19 | 0.21 | 0.99 | ... |
| SAE 4140 A | Experimental | 0.40 | 1.07 | 0.006 | 0.005 | 0.59 | ... | 0.24 | 1.01 | ... |
| SAE 4320 | Experimental | 0.20 | 0.67 | 0.010 | 0.008 | 0.30 | 2.07 | 0.39 | 0.91 | ... |
| SAE 4340 | Fabricated from base material | 0.39 | 0.71 | 0.010 | 0.010 | 0.29 | 1.78 | 0.27 | 0.83 | ... |
| SAE 6130 | Commercial wire | 0.32 | 0.82 | 0.026 | 0.010 | 0.43 | ... | ... | 0.98 | 0.20 |
| SAE 6130 A | Experimental | 0.31 | 1.08 | 0.007 | 0.007 | 0.54 | ... | ... | 0.94 | 0.18 |
| Code A (SAE 6130) | Commercial experimental wire | 0.30 | 0.80 | 0.015 | 0.010 | 0.45 | ... | ... | 1.00 | 0.18 |
| Code B (SAE 6130) | Commercial experimental wire | 0.35 | 1.00 | 0.020 | 0.020 | 0.45 | ... | ... | 1.10 | 0.18 |
| 5% chromium steel | Commercial wire | 0.06 | 0.44 | 0.017 | 0.025 | 0.12 | 0.19 | 0.49 | 5.06 | ... |
| Code C | Commercial wire | 0.27 | 1.41 | 0.018 | 0.015 | 1.61 | 1.82 | 0.42 | 0.18 | ... |
| Mn-Ni-Cr-Mo | Experimental | 0.18 | 1.49 | 0.007 | 0.012 | 0.44 | 1.20 | 0.34 | 0.65 | ... |
| Mn-Ni-Cr-Mo-V | Experimental | 0.25 | 1.17 | 0.008 | 0.012 | 0.65 | 1.83 | 0.80 | 1.17 | 0.21 |

steels and commercial and experimental filler wires. The base steel and commercial filler wires were obtained from commercial suppliers while the experimental filler wires were prepared at Battelle.

### Base Material

The base material used in this work was electric-furnace aircraft-quality alloy steel. The mill analyses and thicknesses of these steels are given in Table 1.

### Commercial Filler Wires

The commercial filler wires and their compositions are listed in Table 2 and are indicated as such under the designated column. The Code A and Code B filler wires were obtained from a commercial supplier and both are modifications of SAE 6130 steel. The Code C filler wire is a proprietary high-silicon steel filler wire. Before use, all of the wires were degreased with carbon tetrachloride and cleaned with fine emery cloth.

### Experimental Filler Wires

In conjunction with the preparation of the experimental heats, analyses of filler wires and their weld-metal deposits were made to determine the efficiency of alloy transfer across the welding arc so that the compositions of the experimental heats could be adjusted to compensate for these losses. This information was important especially where filler wire of the same type as the base metal was used, since it was desired that the weld deposit and base material have the same composition. Pure argon and argon plus 2% oxygen were used as the shielding gases for these tests. Weld pads were made with filler wires; then, both the weld deposits and filler wires were analyzed for carbon, manganese, silicon, chromium and nickel. These analyses are listed in Table 3. The carbon, chromium and nickel losses were small and were independent of the shielding gas used. The silicon loss was also small except for the WF-B weld metal in which 27% silicon loss occurred. The loss of manganese varied depending on which shielding gas was used. When pure argon was used, the manganese loss averaged about 9% and when the argon

Table 3—Arc-Transfer Efficiency of Alloying Elements in $^{5}/_{32}$-in. Diam Filler Wire

| | | Alloying element | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | | Mn | | Si | | Cr | | Ni | |
| Specimen | Shielding gas | Chemical composition, % | Transfer efficiency, % | Chemical composition, % | Transfer efficiency, % | Chemical composition, % | Transfer efficiency, % | Chemical composition, % | Transfer efficiency, % | Chemical composition, % | Transfer efficiency, % |
| SAE 4130 | | | | | | | | | | | |
| filler wire | Argon | 0.22 | | 0.56 | | 0.25 | | 0.96 | | ... | |
| weld metal | | 0.19 | 86 | 0.51 | 91 | 0.23 | 92 | 0.89 | 93 | ... | ... |
| SAE 4140 | | | | | | | | | | | |
| filler wire | Argon | 0.39 | | 0.86 | | 0.25 | | 1.00 | | ... | |
| weld metal | | 0.38 | 97 | 0.76 | 88 | 0.22 | 88 | 0.93 | 93 | ... | ... |
| SAE 4340 | | | | | | | | | | | |
| filler wire | Argon | ... | | 0.71 | | 0.28 | | 0.78 | | 1.74 | |
| weld metal | | ... | ... | 0.69 | 97 | 0.26 | 93 | 0.80† | 100 | 1.76† | 100 |
| SAE 6130 | | | | | | | | | | | |
| filler wire | Argon | 0.27 | | 0.87 | | ... | | ... | | ... | |
| weld metal | | 0.27 | 100 | 0.76 | 87 | ... | ... | ... | ... | ... | ... |
| WF-B* | | | | | | | | | | | |
| filler wire | Argon + 2% | 0.20 | | 0.98 | | 0.70 | | 0.46 | | 0.84 | |
| weld metal | oxygen | 0.19 | 95 | 0.68 | 69 | 0.51 | 73 | 0.44 | 96 | 0.78 | 93 |
| SAE 4130A | | | | | | | | | | | |
| filler wire | Argon + 2% | 0.22 | | 0.73 | | 0.48 | | 1.09 | | ... | |
| weld metal | oxygen | 0.23† | 100 | 0.61 | 84 | 0.48 | 100 | 1.04 | 95 | ... | ... |
| SAE 6130A | | | | | | | | | | | |
| filler wire | Argon + 2% | 0.25 | | 1.14 | | 0.56 | | 0.90 | | ... | |
| weld metal | oxygen | 0.23 | 92 | 0.84 | 74 | 0.50 | 89 | 0.89 | 99 | ... | ... |

* Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, Report No. WCRT L55-92, Sept. 21, 1955.

† The apparent increase of alloy content of weld deposit as compared to filler wire may have been the result of the chemical analysis.

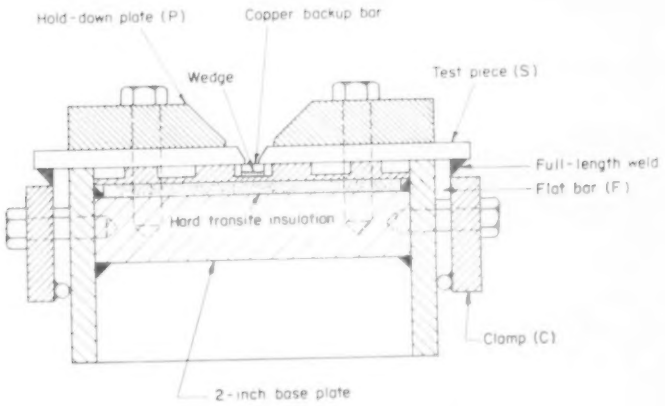


Fig. 1 Schematic diagram of weld-restraining fixture

plus 2% oxygen shielding gas was used, the manganese loss increased to 24%.

The experimental heats of steel were induction melted in a $M_gO$ crucible under an argon-gas atmosphere. Electrolytic iron was used as the melting stock, to minimize the amounts of residual elements. Ingots of these heats were surface ground to remove scale and oxide and then were forged and hot rolled to $\frac{1}{4}$-in. square rod. This rod was annealed in an argon atmosphere, grit blasted and cold rolled to $\frac{1}{16}$-in. square welding wire. A similar procedure was used for fabricating filler wires from base plate. The compositions of the various experimental filler wires are listed in Table 2.

### Test Procedures

Initially, each filler wire, whether commercial or experimental, was given a series of three tests. This series, which covered three major problems in welding these steels, included hot-cracking tests, heat-treatment tests and radiographic examination for weld-metal porosity. The inert-gas tungsten-arc and inert-gas consumable-electrode processes were used throughout this study. A preheat temperature of 200° F was used for all welding and was maintained as the interpass temperature in all multipass welding. From the results of the screening tests, some wires were eliminated, while others which appeared promising were studied further by means of transverse tension tests and Vee-notched Charpy impact tests.

To evaluate the hot-cracking tendencies of the filler wires under study, two types of restrained weld-metal cracking tests were used. The first type, which was used with $\frac{1}{16}$, $\frac{1}{8}$ and $\frac{1}{4}$-in. steel, made use of a weld-restraining fixture. A restrained weld-cracking test, which is a modification of the Lehigh test, was used for the $\frac{1}{2}$- and 1-in. thick plates. The weld-restraining fixture is shown in Fig. 1. Six-in. square pieces of the base material (S) were first clamped in the fixture as shown in the drawing. Then, 2 by 6-in. flat bars (F) were fitted to the bottom side of each test piece and were clamped tightly to the vertical surfaces of the base of the fixture with the side clamps (C). The flat bars then were welded to the test pieces with a full-length weld, after which the hold-down plates (P) were bolted tightly.

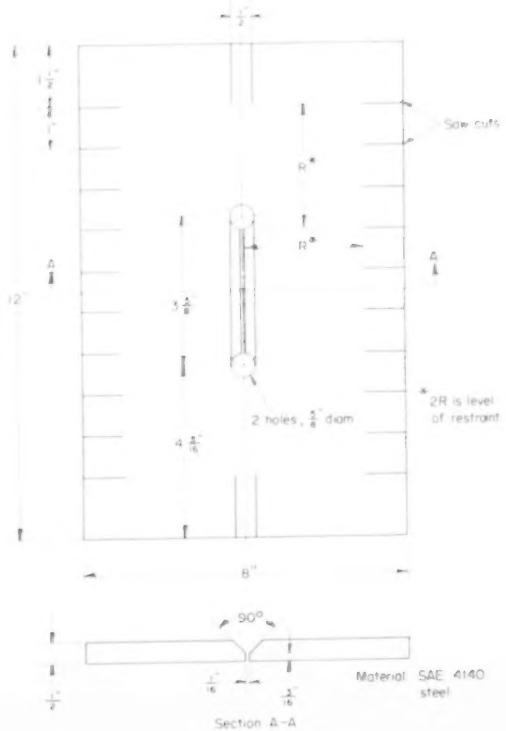


Fig. 2 Design of $\frac{1}{2}$-in. restraint specimen

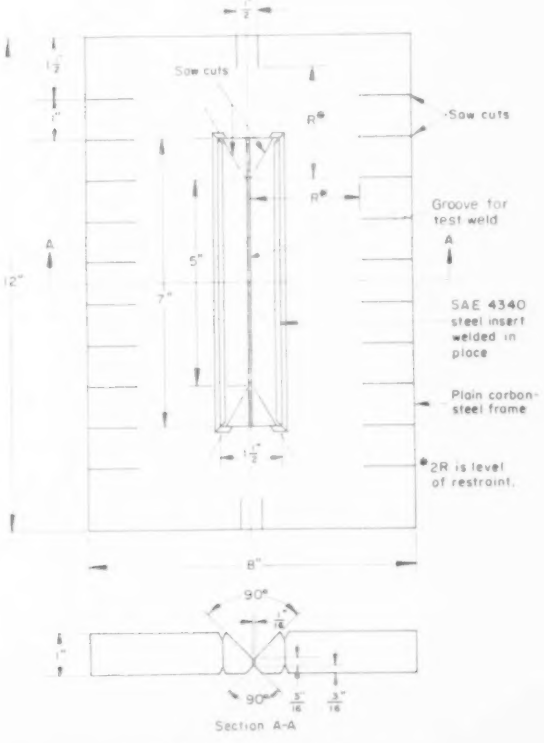


Fig. 3 Design of 1-in. restraint specimen

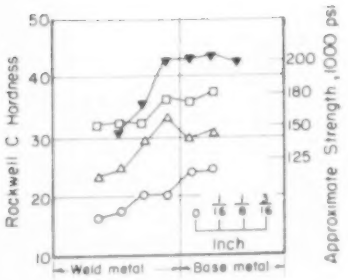


Fig. 4 Hardness gradient across heat-treated weld joints made in 1/4-in. SAE 4130 steel with type 502 steel filler wire

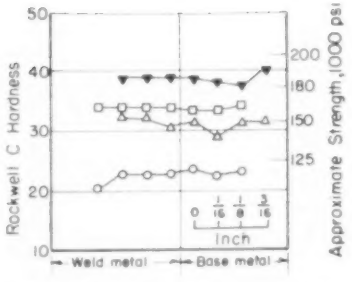


Fig. 5 Hardness gradient across heat-treated weld joints made in 1/4-in. SAE 4130 steel with SAE 4130 filler wire

Thus, the test pieces were restrained from lateral movement and warping. The test weld was deposited by the inert-gas tungsten-arc process, which was used for all the welds in the 1/16-, 1/8- and 1/4-in. material. The restrained-weld-cracking specimens for 1/2-in. SAE 4140 and 1-in. SAE 4340 steels are shown in Figs. 2 and 3, respectively. Both tests are of the Lehigh type, although the 1-in. thick specimen has been modified somewhat in that machined inserts are welded into a plain-carbon-steel restraining frame. This specimen has the advantage that after the test is made the inserts can be removed from the frame and can be broken apart for examination and also the frame can be used for subsequent tests. In the Lehigh-type specimen, the degree of weld restraint is determined by the depth of the saw cuts.

A comparison of the heat-treatment response of the weld deposits and the base materials was obtained by taking hardness readings of both materials after heat treatment. A weld pad was deposited with the various filler wires on pieces of the steel under study. These specimens were given standard base-metal heat treatments to each of four strength levels, 125,000, 150,000, 180,000 and 200,000 psi. The heat treatments consisted of oil or water quenching the specimen from 1550° F and tempering for 1 hr at the desired tempering temperature. (These tempering temperatures are indicated in Figs. 6, 7 and 8.) After heat treatment, the specimens were sectioned, polished and macro-etched with 50% HCl. Rockwell C hardness readings were made of the weld deposit and of the base metal to obtain an approximation of their strengths.

Multipass butt welds made with each of the filler wires were X-rayed to check porosity. Radiographs were made also of multipass butt welds cleaned between passes by light grinding and power wire brushing to determine if the cleaning method had any effect on porosity. Sound welds were obtained using both cleaning methods; however, in subsequent multipass welding, wire brushing was used for convenience.

The transverse-tension tests and Vee-notched Charpy impact tests were made only on those weld metals that satisfactorily passed the screening tests. The heat-treatment tests gave only a general measure of the strengths of the weld deposit, since this test was used primarily to compare the heat treatment

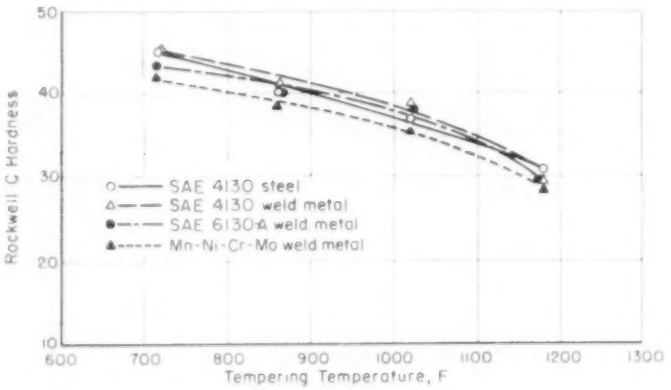


Fig. 6 Comparison of heat-treatment response of various weld metals and 1/4-in. SAE 4130 steel

Material water quenched from 1550° F

Table 4—Results of Transverse-Tension Tests

| *Filler wire* | *Base material* | *Base material hardness, Rockwell C* | *Specimen number* | *Yield strength, psi* | *Ultimate strength, psi* | *Elongation, %** | *Reduction of area, %* | *Location of failure* |
|---|---|---|---|---|---|---|---|---|
| SAE 4130 (commercial) | 1/4-in. SAE 4130 | 37 | 1 | 164,500 | 166,500 | 3 | 9 | Weld metal |
| | | | 2 | 162,500 | 166,000 | 2 | 10 | Weld metal |
| SAE 4130A | 1/4-in. SAE 4130 | 37 | 1 | 163,000 | 169,000 | 3 | 11 | Weld metal |
| | | | 2 | 162,500 | 167,500 | 5 | 13 | Weld metal |
| Mn-Ni-Cr-Mo | 1/4-in. SAE 4130 | 37 | 1 | 166,000 | 173,000 | 10 | 50 | Weld metal |
| | | | 2 | 166,000 | 170,500 | 7 | 34 | Weld metal |
| SAE 4140A | 1/2-in. SAE 4140 | 41 | 1 | 178,000 | 189,000 | 8 | 24 | Weld metal |
| | | | 2 | 180,000 | 190,500 | 11 | 29 | Weld metal |
| SAE 6130 (commercial) | 1-in. SAE 4340 | 41 | 1 | 145,000 | 152,000 | 3 | 7 | Weld metal |
| | | | 2 | 101,000 | 159,000 | 3 | 7 | Weld metal |
| SAE 6130A | 1-in. SAE 4340 | 39 | 1 | 143,000 | 161,000 | 8 | 35 | Weld metal |
| | | | 2 | 147,000 | 177,000 | 7 | 22 | Weld metal |
| Mn-Ni-Cr-Mo-V | 1-in. SAE 4340 | 41 | 1 | 177,500 | 191,500 | 8 | 38 | Base metal |
| | | | 2 | 178,000 | 193,000 | 8 | 40 | Base metal |
| SAE 4340 | 1-in. SAE 4340 | 41 | 1 | 182,000 | 187,500 | 6 | 17 | Base metal |
| | | | 2 | 181,500 | 189,500 | 11 | 34 | Base metal |

* A 2-in. gage length was used on all except the SAE 4140 specimens in which case a 1-in. gage length was used.

of the deposit with the base metal. The transverse-tension test gave a more accurate measure of the joint strength when the weld joint was heat treated to a specific hardness. Three different types of tension-test specimens were required, because of the three different thicknesses of base material used. Standard tension specimens of 0.505 and 0.313 in. diam were machined from weld joints in 1-in. SAE 4340 and ½-in. SAE 4140 steel, respectively. Standard flat-bar-type specimens with cross sections of 0.250 by 0.500 in. were machined from weld joints in the ½-in. SAE 4130 steel. All heat treating of the weld joints was done prior to machining.

Vee-notched Charpy impact tests were made of the three base metals and of the weld deposits made with the most promising filler wires. Test specimens were prepared from the various weld metals and base materials, which were heat treated to selected strength levels prior to the final machining operations. The longitudinal axis of the specimen was perpendicular to the longitudinal axis of the weld joint and to the direction of rolling of the base plate. A 45° Vee-notch with a 0.010-in. root radius was machined perpendicular to the longitudinal axis of the weld joint and to the plate surface of the base material. The heat treatment was checked by taking hardness readings of the specimens before the final machining operations. The impact tests of the material heat treated to various strength levels were made at five temperatures to determine the temperature of transition from ductile to brittle fracture. For these tests, the weld joints in SAE 4130 steel were heat treated to 180,000 psi, in SAE 4140 steel to 200,000 psi and in SAE 4340 steel to 220,000 psi tensile strengths. Additional impact tests of all of these materials which were heat treated to the four standard strength levels were made at room temperature and −65° F.

### Filler Wires Used with SAE 4130 Steel

Nine filler wires were evaluated for use with the SAE 4130 steel. Two of the filler wires had chemical compositions similar to SAE 4130 steel. One of these filler wires was a commercial wire and the other was an experimental filler wire (SAE 4130A) with low sulfur and phosphorus contents. The remainder of the wires were of dissimilar compositions, being SAE 4320, a commercial SAE 6130, two experimental SAE 6130 (Code A and SAE 6130A), Code C, Type 502, and a Mn-Ni-Cr-Mo steel similar to an E10016 weld deposit. The experimental SAE 4130A and 6130A filler wires had compositions which had been adjusted for use with argon plus 2% oxygen shielding gas.

Cracking tests of weld deposits made with these filler wires were produced with

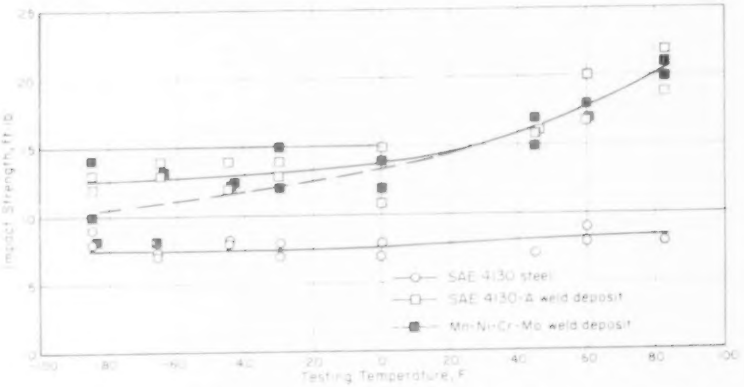


Fig. 7 Vee-notched Charpy impact energy curves for SAE 4130 steel and SAE 4130-A and Mn-Ni-Cr-Mo weld deposits

Materials were quenched from 1550° F and tempered at 800° F

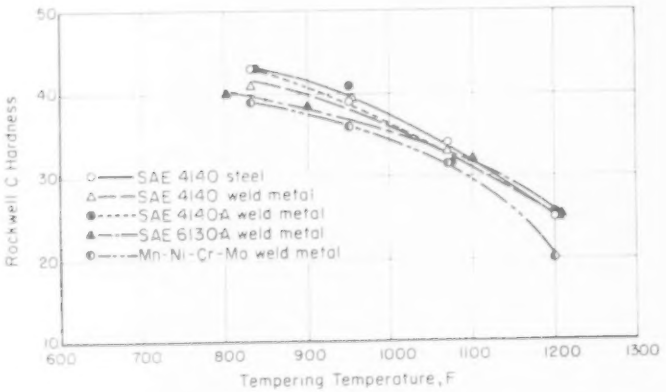


Fig. 8 Comparison of heat-treatment response of various weld metals and ½-in. SAE 4140 steel

Material oil quenched from 1550° F

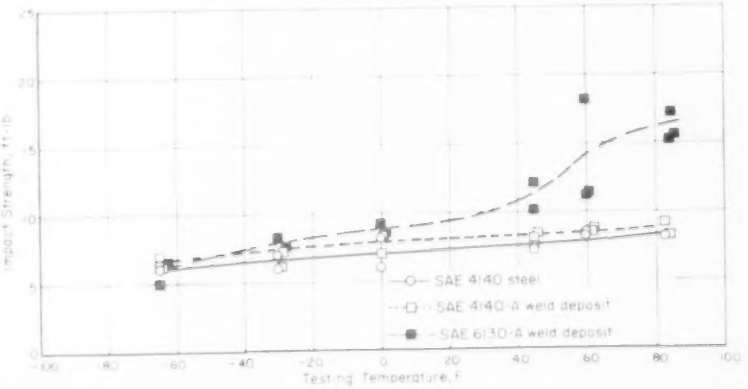


Fig. 9 Vee-notched Charpy impact energy curves for SAE 4140 steel and SAE 4140-A and 6130-A weld deposits

Materials were quenched from 1550° F and tempered at 800° F

the weld-restraining jig. Each wire was evaluated with each thickness of SAE 4130 steel. No cracks were evident in any of the weld deposits made with this series of filler wires. However, it was found that when making multipass welds with the commercial SAE 4130 and 6130 and the Code A filler wires, microcracks occurred in the weld metal. These cracks were too small to be detected in radiographs but were of sufficiently serious nature to affect the mechanical properties of these weld metals. These cracks were eliminated by using filler wires that had been fabricated from the low-sulfur, low-phosphorus SAE 4130A and 6130A steels.

Radiographs of all the weld deposits indicated that only fine scattered porosity occurred occasionally. All welds were acceptable according to Standard II, as set forth in U. S. Army Specifications No. 57-0-8, dated Sept. 30, 1949, "Radiographic Standards for Inspection of Arc and Gas Welds in Steels." Standard I of these specifications requires a complete absence of porosity and many of the welds met this standard also.

Weld deposits from two of the filler wires did not respond to heat treatment in the same manner as the SAE 4130 steel. The hardnesses of the Type 502 deposits were much less than those of the base materials at all four strength levels. The SAE 4320 weld deposits had hardnesses comparable with those of the SAE 4130 base material at 125,000 and 150,000-psi strength levels, but would not heat treat to the upper strength levels of 180,000 and 200,000 psi. The remainder of the weld metals had a heat-treating response very nearly the same as that of the SAE 4130 steel. Typical examples of heat-treating test results are shown in Figs. 4 and 5. The heat-treating characteristics of the Type 502 steel wire were unsatisfactory, while those of the SAE 4130 wire were good. The tempering curves of the acceptable filler wires are shown in Fig. 6.

On the basis of the above tests, the two SAE 4130 and 6130 filler wires, and the Mn-Ni-Cr-Mo steel filler wire were selected for transverse-tension and notched-bar tests. The weld joints intended for tension testing were given base-metal heat treatments to about Rockwell C 37 (170,000 psi). The tension-test results are shown in Table 4. Although the weld-joint strengths were satisfactory, the elongation of the joints made with the SAE 4130 filler wires was somewhat low.

The Vee-notched Charpy impact test results of the weld metals and base steel are given in Table 5 and Fig. 7. The impact properties of the SAE-4130 steel used in the tests to determine the transition temperature from ductile to brittle fracture at 180,000-psi tensile strength were rather poor (Fig. 7). This steel was laminated which would account for its poor impact performance. Steel from a different heat was used when making the impact tests at the various strength levels (Table 5) and better impact properties were obtained than for the material heat treated to 180,000 psi. The SAE 4130A and the Mn-Ni-Cr-Mo weld metals (Fig. 7) both had better impact properties than the SAE 6130A weld metal. (For clarity, the curve for the SAE 6130A weld metal is shown in Fig. 9.) The specimens that were tested at the various strength levels (Table 5) were made with pure argon as the shielding gas while those specimens used to determine the transition temperature were made using argon plus 2% oxygen as the shielding gas. The alloy content of the welds made using the pure argon shielding gas, therefore, would be somewhat higher than that of the welds using the mixed shielding gas, and better impact properties would be expected. This is shown by the fact that at 180,000 psi, the Mn-Ni-Cr-Mo weld metal has higher room-temperature impact properties when pure argon shielding gas was used than when the argon plus 2% oxygen shielding gas was used. The lower impact values of the commercial SAE 4130 weld metal as compared with the SAE 4130A weld metal was due to microcracking which occurred in the former.

Table 5—Results of Impact Tests*

| Filler wire | Base material | Vee-notched Charpy impact values, Base-metal strength level, psi — 125,000 — 28° F | — 125,000 — −65° F | — 150,000 — 28° F | — 150,000 — −65° F | — 180,000 — 28° F | — 180,000 — −65° F | — 200,000 — 28° F | — 200,000 — −65° F |
|---|---|---|---|---|---|---|---|---|---|
| | ½-in. SAE 4130 | 39 | 35 | 60 | 57 | 38 | 22 | 19 | 10 |
| SAE 4130 | ½-in. SAE 4130 | 46 | 36 | 23 | 10 | 12 | 6 | 10 | 5 |
| Mn-Ni-Cr-Mo | ½-in. SAE 4130 | 112† | 59 | 70 | 27 | 42 | 8 | 20 | 6 |
| | ½-in. SAE 4140 | 66 | 60 | 46 | 42 | 32 | 16 | 23 | 12 |
| SAE 4140 | ½-in. SAE 4130 | 84 | 44 | 56 | 20 | 29 | 12 | 20 | 10 |
| Mn-Ni-Cr-Mo | ½-in. SAE 4140 | | | 82 | 28 | 36 | 13 | | |
| | 1-in. SAE 4340 | 46 | 36 | 44 | 38 | 22 | 18 | 17 | 10 |
| SAE 4340 | 1-in. SAE 4340 | 54 | 47 | 56 | 50 | 30 | 22 | 22 | 14 |
| SAE 6130 | 1-in. SAE 4340 | 74 | 43 | 40 | 7 | 33 | 12 | 29 | 14 |
| Mn-Ni-Cr-Mo-V | 1-in. SAE 4340 | 38 | 14 | 40 | 16 | 22 | 7 | 20 | 6 |

* Values are averages of two tests made at each condition.
† Specimen did not break completely.

## Filler Wires Used with SAE 4140 Steel

Two SAE 4140, three SAE 6130, Type 502, Code C, and the Mn-Ni-Cr-Mo steel filler wires were used to weld the ½-in. SAE 4140 steel. One of the SAE 4140 filler wires, fabricated from base plate as noted in Table 1, had a rather high sulfur content (0.021% sulfur). Since it was believed that this

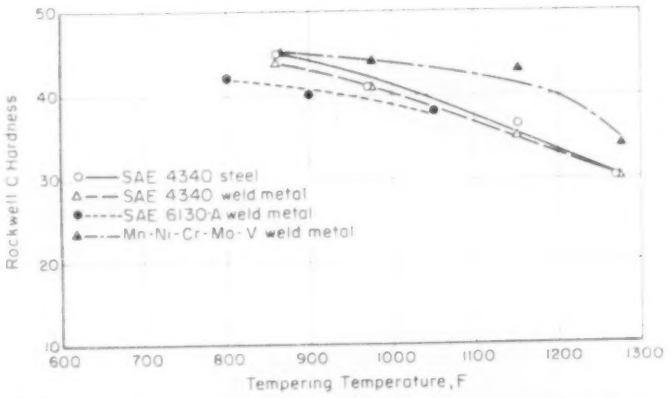


Fig. 10 Comparison of heat-treatment response of various weld metals and 1-in. SAE 4340 steel

Material oil quenched from 1550° F

residual would affect the cracking resistance of the weld deposit,[5,6] a second filler wire of this type (SAE 4140A) was prepared with 0.006% phosphorus and 0.005% sulfur. Thus, the crack sensitivity of two weld deposits of similar composition except sulfur content could be compared. A modified SAE 6130 wire (Code B) was evaluated as well as the commercial and experimental (SAE 6130A) wires of standard composition.

The Type 502 steel filler wire did not meet the heat-treatment requirements. As before, when compared with the SAE 4130 steel, the weld-metal hardnesses fell considerably below those of the SAE 4140 base material at each strength level. The Mn-Ni-Cr-Mo weld-metal hardnesses also were somewhat below those of the base steel except at around 150,000 psi where they compared favorably. At the two highest strength levels, the hardnesses of the SAE 6130A weld metal were a little lower than the base-metal hardness but they matched closely at the 125,000- and 150,000-psi strength levels. The remainder of the weld metals responded satisfactorily to heat treatments. Tempering curves of the SAE 4140, SAE 4140A and Mn-Ni-Cr-Mo weld-metal deposits and SAE 4140 steel are shown in Fig. 8.

The ½-in. thick Lehigh-type restrained-weld-cracking specimen was used to check these filler wires for resistance to cracking. The Code C wire had fair cracking resistance, while the SAE 4140 and 6130 and the Code B wires were quite poor in this respect. The low cracking resistance of these four wires was attributed to their high sulfur and phosphorus contents. The experimental SAE 4140A and 6130A and Mn-Ni-Cr-Mo weld metals with their low sulfur and phosphorus contents had excellent cracking resistance.

Transverse tensile-strength properties of welded joints made with the experimental SAE 4140A filler wire are shown in Table 4. These welded joints were given a base-metal heat treatment to Rockwell C 41 (190,000 psi) prior to machining. It may be seen that nearly 100% joint efficiency was obtained.

Vee-notched Charpy impact tests were conducted on the SAE 4140A and Mn-Ni-Cr-Mo weld metals. The results are shown in Fig. 9 and Table 5. The impact properties of the SAE 4140A filler wire and the SAE 4140 base metal were very similar over the entire temperature range at the 200,000-psi strength level. Measurements taken at the base of the notch of the fractured specimen indicated that the weld metal had a little greater lateral contraction than did the base metal, e.g., 1.5% versus 1.0% at 0° F. The difference between the results in Fig. 9 and those shown in Table 5 at the 200,000-psi strength level is due to a variation in heat treatment. The specimens used in the transition-temperature tests were heat treated to the upper limits (Rockwell C 41 +) of the 200,000-psi range, while the specimens whose properties appear in Table 5 were heat treated to the lower limits of the range (Rockwell C 41). The Mn-Ni-Cr-Mo weld deposit was tested only at the 150,000- and 180,000-psi strength levels, since its heat-treatment response matches that of the SAE 4140 steel only in this midrange. The impact properties of this weld metal at room temperature were very good and at −65° F were about the same as the SAE 4140 base metal.

## Filler Wire Used with SAE 4340 Steel

One of the filler wires of this series was fabricated from the SAE 4340 base plate. The filler wires of dissimilar composition were SAE 6130 and 6130A, Code B, Code C, Type 502, and a Mn-Ni-Cr-Mo-V steel similar to the composition of an E15016 weld deposit.

Only the SAE 4340, experimental SAE 6130A and Mn-Ni-Cr-Mo-V filler wires appeared satisfactory from the screening tests. The other wires had the same poor weld-metal characteristics that occurred when used with the SAE 4140 steel, such as poor cracking resistance and/or response to heat treatments.

As it was expected, the SAE 4340 weld deposit had heat-treatment response almost identical with that of the SAE 4340 base plate, as shown in Fig. 10. The Mn-Ni-Cr-Mo-V steel weld-metal hardness was the same as the base-plate hardness at the lowest tempering temperature (200,000 psi), but as the tempering temperature was increased, the weld hardness did not decrease so rapidly as the base-metal hardness. The SAE 6130A weld-metal hardness matched only at the lowest strength level; at the higher strength levels, the hardness of the weld was lower than that of the base steel.

Both weld metals had excellent cracking resistance and complete lack of porosity as determined from radiographs.

By referring to Table 4, the strength and ductility may be seen for SAE 4340, commercial and experimental SAE 6130, and the Mn-Ni-Cr-Mo-V welded joints heat treated to a base-metal hardness of Rockwell C 41 (190,000 psi). The base-metal hardness of the SAE 6130A specimens was a little less, Rockwell C 39. The SAE 6130 weld metal had several microcracks which accounted for its low properties. Better results were obtained with the SAE 6130A filler wire but the strength was still somewhat low, due to the difference in heat-treatment response. The weld joints made with the SAE 4340 and Mn-Ni-Cr-Mo-V filler wires were as strong or stronger than the base material since the failures occurred in the base metal.

Impact tests of the SAE 4340 steel, 4340 weld metal and Mn-Ni-Cr-Mo-V weld metal heat treated to 220,000 are plotted in Fig. 11. The impact properties of the three materials are quite similar at this strength with the Mn-Ni-Cr-Mo-V weld metal having slightly greater impact strength at the higher temperatures. At the lower strength levels, (Table 5), the SAE 4340 weld metal had much better impact properties than either the Mn-Ni-Cr-Mo-V weld metal or SAE 4340 steel. The impact strength of the SAE 6130 welds decreases very rapidly for the higher strength levels which might be due to the precipitation of vanadium carbide at certain tempering temperatures. This seems especially true, since the tempering temperatures for the three strength levels where the impact strengths at −65° F are low fall in the

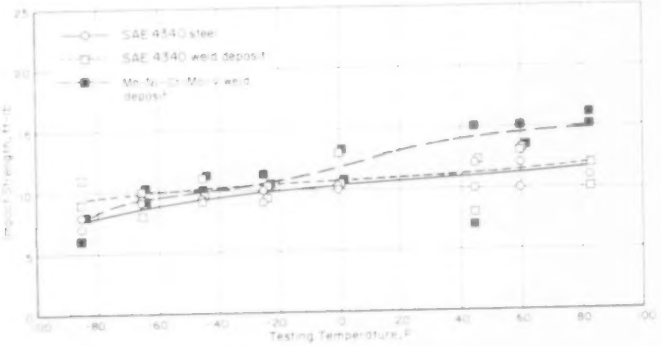


Fig. 11 Vee-notched Charpy impact energy curves for SAE 4340 steel and SAE 4340 and Mn-Ni-Cr-Mo-V weld deposits

Materials were quenched from 1550° F and tempered at 900° F

temperature range where temper brittleness is most serious.[3] This could be considered the cause of the low impact strengths of the Mn-Ni-Cr-Mo-V weld metal at −65° F at the different strength levels.

## Conclusions

The purpose of this study has been to develop at least two filler wires for welding each of the three steels. For each steel, one filler wire of a composition similar to that of the base steel and at least one wire with a dissimilar composition has been developed. In general, the filler wires with a composition similar to that of the base steel are the best.

The SAE 4130A and the Mn-Ni-Cr-Mo filler wires were the best suited for welding SAE 4130, $\frac{1}{4}$ in. or less in thickness. The heat-treatment response of both filler wires was nearly the same as the base steel although the ductility was somewhat lower than desired. Both filler wires had excellent cracking resistance. The SAE 6130A filler wire could be used also for welding this steel, although its impact properties were not so good as those of the other two weld metals.

The best filler wires for use with the $\frac{1}{2}$-in. SAE 4140 steel were the SAE 4140A and the Mn-Ni-Cr-Mo steels. The SAE 4140A weld metal had good cracking resistance, heat-treating characteristics and strength properties. Its impact strengths were not so good as those obtained with other filler wires used with other steels, but were nearly the same as those of the base material. The Mn-Ni-Cr-Mo filler wire would be satisfactory for use at around the 150,000-psi strength level. However, at the other strength levels there is a difference in the heat-treating characteristics of this weld metal and the SAE 4140 steel. The SAE 6130A filler wire might be used at the lower strength levels.

The 1-in. SAE 4340 steel was welded satisfactorily with either the SAE 4340 or the Mn-Ni-Cr-Mo-V filler wires. The Mn-Ni-Cr-Mo-V weld-metal hardness overmatches the base material at the lower strength levels. The SAE 4340 weld deposit has better impact properties at the lower strength levels, but both weld metals have similar impact properties at the higher strengths.

*Acknowledgment*

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# A VIBRATING ELECTRODE HOLDER

BY L. LANYI

An electrode holder was fitted with an electromagnetic vibrator to impart axial vibration to the electrode. Covered bronze electrodes of Czechoslovakian manufacture were tested in the holder in an effort to improve the stability of the arc. The amplitude of vibration (up and down) was 0.024 in. The vibration improved the arc stability and allowed the use of lower currents than without vibration. Porosity was eliminated by vibration.

Tests with $\frac{1}{16}$-, $\frac{5}{32}$- and $\frac{3}{16}$-in. low-hydrogen electrodes at 120 to 210 amp, direct current, reverse polarity showed little effect of vibration on melting rate. The globular transfer associated with low-hydrogen electrodes was not changed by vibration.

Abstract by **Gerard E. Claussen** of "Knitajuci Drzak Elektrod," published in *Zvarenie*, **5**, 372–374 (December 1956).

Dr. Claussen is associated with Development Laboratories, Linde Co., Newark, N. J.

# TRANSVERSE WELD SHRINKAGE

BY W. GILDE

A new formula has been derived for the transverse shrinkage across butt welds made by any electric arc process.

Abstract by Gerard E. Claussen of "Beitrag zur Berechnung der Querschrumpfung," published in Schweisstechnik (Berlin) **7**, 10-14 (1957). The author is on the staff of the Central Welding Institute, Halle, E. Germany.

Dr. Claussen is associated with the Development Labs., Linde Co., Newark, N. J.

$$\Delta L = \frac{0.24 \times 6000 \times K \times A \times V \times I \times B}{T \times U \times L}$$

- $\Delta L$ = shrinkage in in.
- K = proportion of arc heat absorbed in the plate. Values from 0.42 to 0.75 are used. The lower values apply to surface beads, the higher values to root beads.
- A = thermal expansion coefficient, $15 \times 10^{-6}$ for steel.
- V = arc voltage.
- I = welding current, amp.
- B = temperature conductivity, $cm^2$/sec.
- L = thermal conductivity, cal/$cm^2$/°C/sec.
- $\frac{B}{L}$ = 1.1 for steel.
- T = plate thickness, mm.
- U = travel speed, cm/min.

The formula agreed well with measurements on mild- and stainless-steel welds. Good judgment is required in selecting the appropriate value of K.

# HIGH-VACUUM ELECTRON-BEAM FUSION WELDING

*Objective of newly-developed welding process is to weld in a high vacuum without introducing any contaminating material into the system as a part of the welding operation*

BY W. L. WYMAN

## Introduction

Several of the materials required in the rapidly expanding fields of atomic energy and rocket development have very recently emerged from the stage of rare metals found in the development laboratories into standard production-line materials used on a large scale. The requirements for the large-scale fabrication of materials such as zirconium, titanium, molybdenum and their alloys have introduced problems in joining which have resulted in a major evaluation of the welding techniques suitable for application on these materials. Much effort has been extended to the application of the inert-gas-shielded arc-welding processes for joining the materials and the results of this work have been very satisfactory for many applications. The efforts along this line have also pointed up several short-comings of these inert-gas-shielded arc processes which open the field for the development of new or improved processes for use in fabricating these new materials. As a result of this need for improved welding tools, a new process has been developed which offers several advantages in welding certain materials.

W. L. Wyman is Welding Engineer associated with the General Electric Co., Richfield Work.

## Objective

The objectives of this process development were:

1. Develop a method of fusion welding in a high vacuum without introducing any contaminating material into the system as part of the welding operation.
2. Develop a method which permits complete control of the welding variables as the weld is progressively made.
3. Develop a process which has a wide range of application without equipment modification once installed.
4. Develop a system that is suitable for application to production welding.
5. Develop a process which will yield results superior to other methods of welding now available on the reactive materials.

## Process

The welding process, *vacuum weld*, consists of bombarding two pieces to be fusion welded with a beam of electrons in a high-vacuum chamber. The basic elements of this welding process, Fig. 1*A*, and Fig. 1*B* are:

1. A tungsten cathode to emit a larger number of electrons.
2. A high potential, several thousand volts, between the cathode and

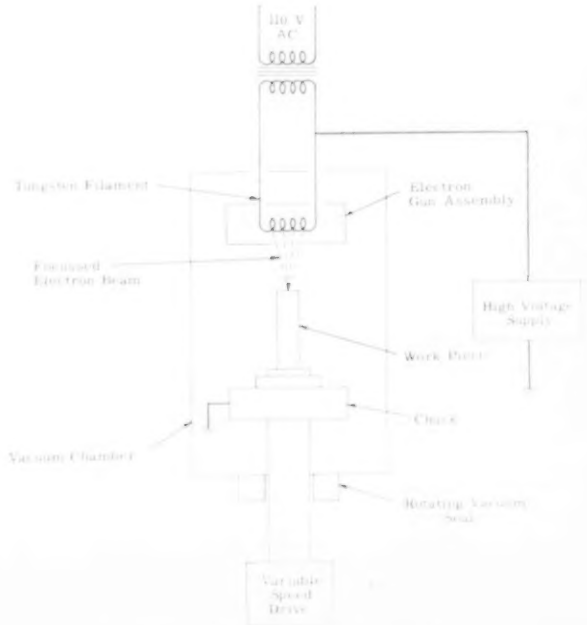



Fig. 1A Schematic of vacuum-welding system

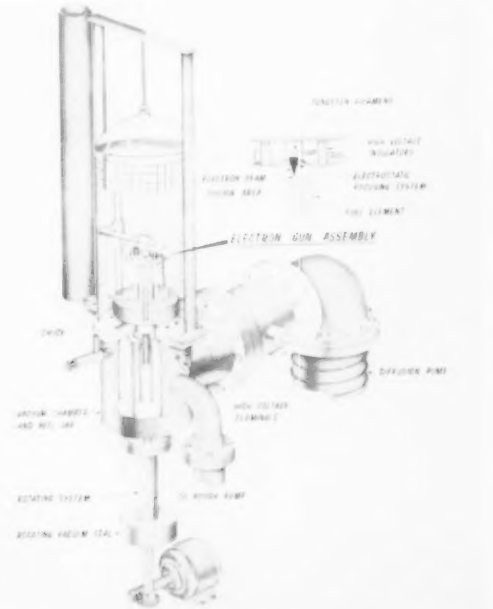



Fig. 1B Vacuum-weld working system

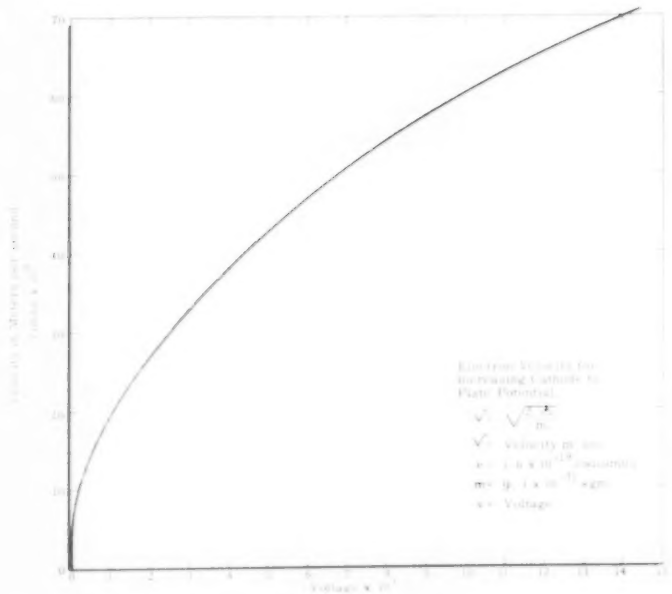


Fig. 2 Plot of electron velocity

plate to accelerate the electrons.

3. A focusing system to form the electrons into a beam.

4. A vacuum chamber and pumping equipment that can maintain a pressure of $5 \times 10^{-3}$ mm of mercury or less which surrounds the assembly.

The tungsten filament in the form of a spiral wire is heated to above 2000° Kelvin and thermionic emission of electrons in large quantities takes place from the surface of the filament. For a current of 250 milliamperes, approximately 1.5 x $10^{18}$ electrons per sec are emitted from this tungsten filament. A high voltage between the cathode and pieces to be welded imparts velocity, Fig. 2, to the electrons. Energy is a function of the velocity of the electrons, and the higher the voltage potential for the same current the greater the energy delivered to the weld. The normal working range of voltage for this process is from 1700 to an estimated 15,000 volts. The restriction of 15,000 volts is placed as the upper limit of usability before hard X-rays that can penetrate the vacuum chamber walls are generated. However, with proper radiation shielding higher voltages could be used, but it is doubtful if any material gain in process advantages could be achieved. During the period when the electrons are being accelerated to the weld area, they are also being focused into a beam with a spot focus. This focusing is accomplished by a simple electrostatic focusing system which utilizes the high potential of the system. It is necessary to focus the electron beam so that the concentration of electrons striking a small localized area to be welded is sufficient to raise the temperature of this area to the melting point. Most of the kinetic energy of the electrons is converted to heat upon striking the workpieces and when the total energy going into the localized area is greater than the capacity of the material to conduct the heat away, melting takes place. As the material is melted, the two edges flow together and, by progressively moving the pieces to be joined beneath the beam, a fusion weld results. The beam spot diameter found suitable for this work ranges from $\frac{1}{16}$ in. diam for thin material, 0.005 in., up to $\frac{1}{8}$-in. diam for heavy material, $\frac{1}{4}$-in. thick.

## Equipment

The equipment required for this process consists of a vacuum chamber which can be pumped down to a pressure of at least $5 \times 10^{-3}$ mm of mercury. A high-voltage supply which must have a range of from 1700 to 15,000 volts dc, and from 10 to 2000 (estimated) milliamperes if all applications are to be covered, an electron gun assembly, and a work supporting and driving system.

## Range of Application

Most of the work to date has been directed toward the development of Zircaloy-2 welding procedures. This is a 1.5% tin, 0.12% iron, 0.10% chromium, 0.05% nickel alloy, with the balance zirconium. However, a very brief investigation to determine what materials could be handled with this process was made. Most of the common metals used today can be welded. For example, tungsten, molybdenum, titanium, nickel, zirconium and several stainless-steel alloys have been welded satisfactorily.

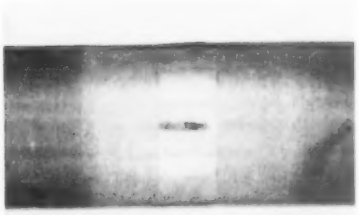
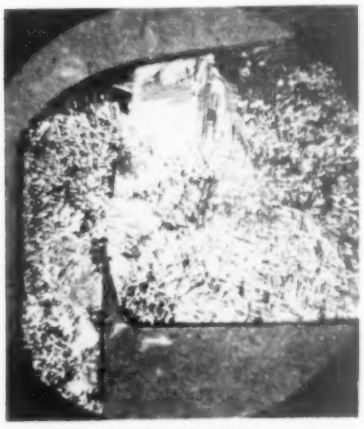


Fig. 3 Butt weld in Zircaloy-2 tubing. X 2

The apparent black area in the center of the weld is caused by light reflection in photographing

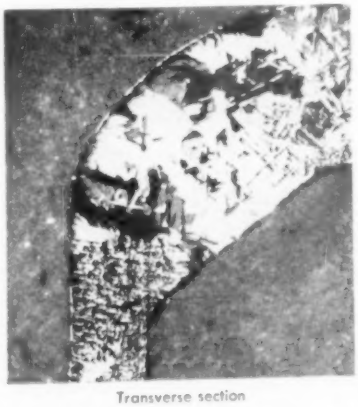


Transverse section

Fig. 4 Vacuum weld of Zircaloy-2 cap to can. X 15

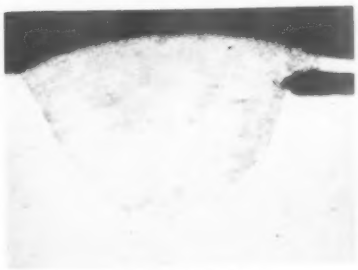
Transverse section

Fig. 5 Stainless-steel butt weld. X 25



Transverse section

Fig. 6 End-cap weld in 0.020-in. Zircaloy-2 can to 0.040-in. cap. X 30



Transverse section

Fig. 7 Vacuum weld joining 0.005-in. stainless-steel tubing to heavy end plug. X 20

*The notable exception has been aluminum. Welds made on aluminum do not compare in quality or appearance to welds made on aluminum with the more conventional processes. This appears to be caused by the oxide film on the melt surface. The electron beam does not effectively break up this oxide film. This phase has not been investigated to any extent and further work along this line is planned with the aim of making possible the welding of aluminum by this process.

On Zircaloy-2, a thickness range of from extremely thin, 0.005 in. thick, up to ¼-in. thick material has been welded using this process. Although this is the range of thicknesses welded to date, certainly the potential range may be extended as the process is developed more fully.

The process has been used on many joint designs including butt joints, lap joints, edge joints, plug welds, fusion spot welds, and to join thin sections 0.005 in. to heavy sections. The application of this process follows the same general pattern that would be used in inert-gas-shielded tungsten-arc welding, and can be considered an all-position process. This process has been used to fuse two surfaces together and no attempt has been made to add filler wire to the joint, although this could be done quite easily with the proper vacuum chamber.

* More recent work has led to a suitable combination of factors which make possible the welding of aluminum alloys with ease.

## Characteristics of the Process

This process differs from the normal fusion welding processes in several ways.

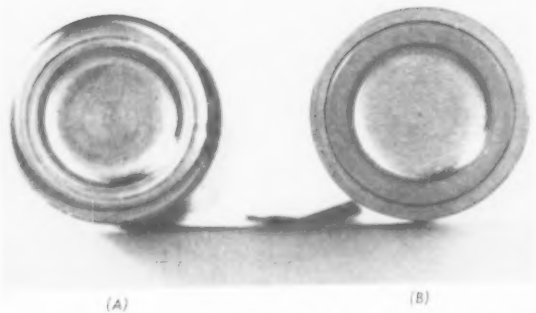
The welding operation must be done in a vacuum chamber. This requirement introduces certain advantages as well as certain disadvantages. The most important disadvantage with this process is that after evacuation only a limited amount of adjustment of the physical location of the components in the system is possible. This factor of working inside a sealed chamber also can be considered one of the advantages of the process. Any work must be set up to be welded almost fully automatically. Therefore, the common problem of the operator variable affecting uniformity of product is greatly reduced and the benefits of automatic welding are obtained.

The process has a built-in protection against any weld being made under conditions of poor atmospheric protection. A high-voltage arc discharge will occur at pressures above about $5 \times 10^{-3}$ mm of mercury. This restricts welding until a sufficiently low pressure is reached, $5 \times 10^{-4}$ mm of mercury, so that a minimum atmospheric purity of 99.999987%, surrounds the parts to be welded. The arc-discharge condition at high pressures is related to the mean free path of the electrons. When the mean free path is short because of a number of gas molecules in the space between the cathode and the workpieces, the electrons strike these molecules and form ions. When the ion concentration in this area is high, an arc discharge between the high-voltage components can occur.

At the highest working pressure suitable for the process, the effective purity of the atmosphere in the chamber is 99.999987%. This can be compared with welding grade helium which has a minimum purity of approximately 99.99%, and welding grade argon with a minimum purity of approximately 99.95%. The high purity necessary for this process assures that one of the variables, gas shielding, normally used in fusion welding of the reactive materials is eliminated. The atmosphere of extremely high purity completely surrounds the parts to be welded. This eliminates the requirements for rapid-quenching jigs to limit the time the weld area is at elevated temperature and, therefore, subject to contamination by gases. The purity of 99.999987% is the upper limit of working range successfully used to date. However, by going to lower pressures in the system, purities on the order of 99.9999987% can be easily obtained.

Another characteristic of this process which is very important is the heat input into the parts to be welded. The energy input into the weld area is very soft. That is, no apparent force is exerted on the molten puddle. As a result, no crater can be observed at any time, and the weld stopping point is difficult, and sometimes impossible, to detect when a cylindrical weld is completed. This soft heat input makes the control of welds on thin material, 0.005 in., very easy. No force tends to drive through and blow holes in the workpieces and the power into the weld can be controlled over the full range of from zero up to maximum desired wattage. No appreciable surface disturbance or contour change is noted when comparing the fusion area with the adjacent base metal, and very-wide fusion zones with respect to the workpiece-material thickness can be carried. This assures smooth, notch-free welds.

The effect of contamination from the welding equipment is not encountered with this process. Nothing in the system breaks down during welding and the electrons which make up the energy source do not react with the molten puddle. Any stray ions that may be formed as a result of an electron colliding with a molecule of residual gas would carry a plus charge in most cases and as a result would be attracted to the negative cathode instead of the workpieces. This factor tends to increase



(A) (B)

Fig. 8 Fuel element end plug (A) before and (B) after welding (Zircaloy-2). X 3

Weld face bend | Weld root bend | As-received material

Fig. 9 Weld bend test—butt-welded Zircaloy-2. X 3

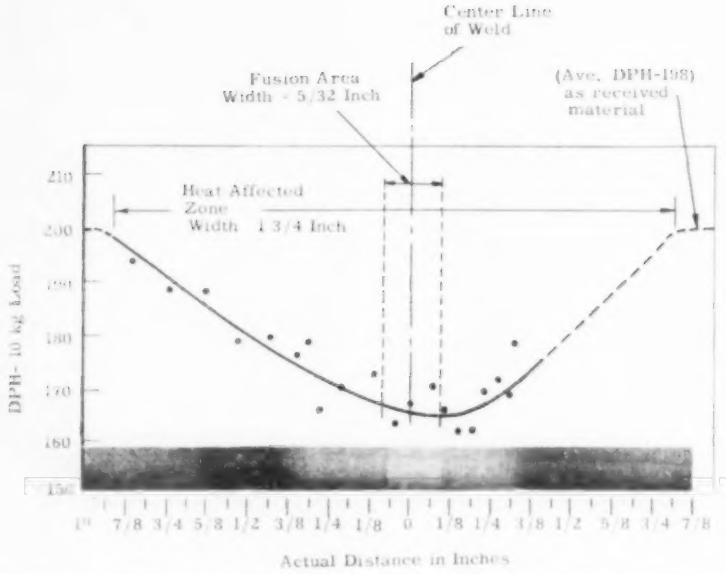



Fig. 10 Vacuum-weld hardness traverse on butt-welded 0.035-in. Zircaloy-2 material. X 2

the potential purity in the weld area over the actual calculated value. A pure heat source of this type, coupled with the extreme purity of the surrounding atmosphere, results in a method ideally suited for the melting of the reactive metals without danger of contamination.

### Operation Appearance

During the welding operation, the only visual effect is the melting of a localized area beneath the electron beam. The electron beam itself cannot be seen; only the effect is detectable. The process can be viewed through a number four welding glass. This is required to discern the condition of the molten pool. As mentioned before, the puddle does not appear disturbed in any way and the heat input into the workpieces is very smooth. Control of the weld can be accomplished either by visual observation and adjustment or by automatic controlled power input into the weld. By control of the focus of the electron beam, the melt area can be made larger or smaller as desired. This control of the melt area is very helpful in welding thin, 0.005-in. material, where an extremely small melt area is desired. The penetration pattern is controllable and is a function of the power into the weld and the travel speed. This penetration can be controlled to yield 100% or anything less as desired. The only requirement is a sufficiently-large high-voltage power supply to handle the thickness of material being welded.

### Weld Appearance

Welds made with this process have a uniform width of fusion (Fig. 3) and a very smooth, clean, mirror-like surface. The root side of the weld appearance is the same as the face side. No crater or other surface disturbance is detectable.

Microsections of many welds (Figs. 4, 5, 6 and 7) were inspected to determine the weld quality and the fusion pattern. In no case, on either stainless steel or Zircaloy-2, was weld porosity observed. The quality of the weld was of the highest order and penetration was satisfactory.

The observed quality of welds from the standpoint of surface and microstructure were superior to welds made by conventional processes on these materials.

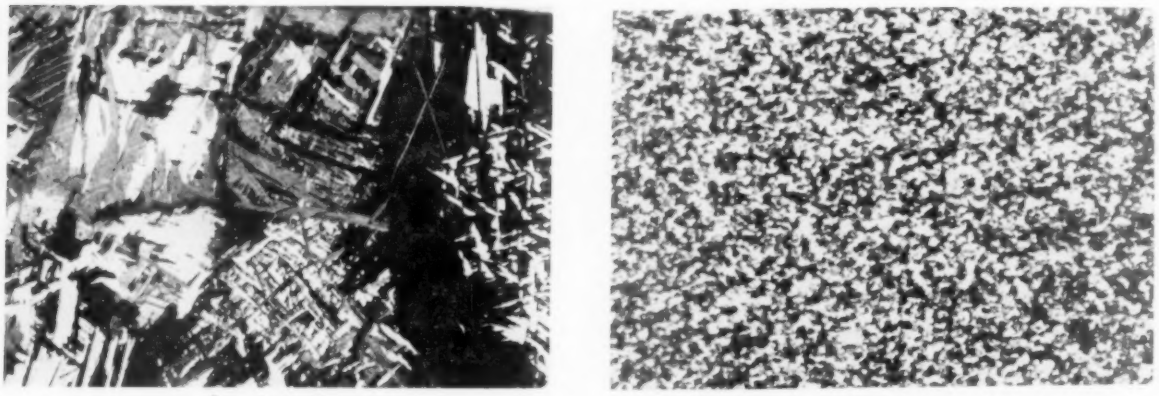
### Welding Conditions

Several different types of joints have been used to evaluate the process. A square butt joint in $\frac{1}{2}$-in. diam, 0.035-in. wall Zircaloy-2 tubing was used for mechanical-properties test specimens. Figure 3 is a photograph of a tube joint as welded, ready for cutting into test specimens. A second type of joint consists of a 0.078-in. thick Zircaloy-2 end plug slipped into the 0.035-in. Zircaloy-2 tubing. Figure 8*A* shows a joint of this type ready for welding, while Fig. 8*B* shows the completed end cap weld. Micrographs of this type of joint (Fig. 4) were made to inspect the effect and pattern of the fusion area. Bead contour, penetration and weld quality were observed.

Stainless steel, Type 304, was welded using the same general joint designs. Figure 5 is a photomicrograph of a square butt weld joining two pieces of stainless-steel tubing. The welding conditions used for both the Zircaloy-2 and the stainless-steel joints were: a pressure of $1 \times 10^{-4}$ mm of mercury, purity of 99.999987%, 3900 volts dc and a current of 22 milliamperes at the power supply. The travel speed was 5 ipm.

### Properties of Welds

In all cases in this report, the me-



Transverse section
Zircaloy-2 butt weld. Grain size 0.432 mm, ASTM No. 0–00

As-received Zircaloy-2 material. Grain size 0.016 mm. ASTM No. 9

Fig. 11 Grain size comparison between weld and as-received Zircaloy-2 material. X 80

chanical and other properties of welds made with this process are restricted to Zircaloy-2 alloy. The factors investigated were tensile strength, ductility, structure, hardness and corrosion rates. Table 1 compares the mechanical properties of *vacuum welds* and as-received material.

heat-affected zone near the fusion line both have the same hardness within the accuracy of the testing machine. The higher hardness away from the weld is caused by the 13% cold work in this material before welding.

The weld area and the heat-affected zone exhibit the characteristic trans-

Table 1—Comparison of Mechanical Properties

| *Property* | *Vacuum weld* | *As-received material, 13% cold worked* |
|---|---|---|
| Tensile strength | 92,900 psi | 96,000 psi |
| Reduction of area | 38.7% | 36.2% |
| Controlled bend test | (face) 1/2T* | 3/4T |
| | (root) 1/2T | |
| Hardness DPH† | 166 (Ave.) | 198 (Ave.) |
| Grain size ASTM No. | Between 0 & 00 (0.432 in.) | No. 9 (0.016 mm) |

* T = material thickness.
† Diamond Pyramid hardness (10-kg load).

The slightly lower tensile strength can be caused by the effects of annealing in the fusion zone. This also would account for the slightly higher value for the reduction of area. The controlled bend test was taken as the second measure of ductility, Fig. 9; in this case, it was difficult to obtain the exact point of failure as indicated by face cracking. The weld area has approximately the same tensile strength and ductility as the as-received material, as determined within the limits of the testing equipment.

A plot of DPH hardness vs. weld position (Fig. 10) indicates that the molten weld puddle was not contaminated during the welding cycle to any extent which caused an increased hardness in that region. The fusion area and the formed beta structure of zirconium quenched from above the alpha-beta transformation temperature. The large grain size developed in fusion welding zirconium alloys, Fig. 11, should be held to a minimum by welding as rapidly as possible.

A corrosion test to determine the effect of welding this Zircaloy-2 material on corrosion resistance to 686° F water is now in progress. The results after 70 days are that no difference in the corrosion rates between welds, heat-affected zones, or as-received material has been detected.

## Conclusions

1. This process makes possible fusion welding with no contamination introduced into the welding area by the welding process.

2. This process makes possible production welding in atmospheres of extreme purity, 99.999987% or better.

3. Containers can be fusion welded so that the residual gas in the vessel is very small. Controlled by the degree of vacuum obtainable.

4. For metals which react with gases at elevated temperature and become contaminated, this process offers a means of welding which assures no detectable absorption.

5. This process is suitable for production welding on certain applications.

6. Under certain conditions this process is cheaper than conventional welding methods.

7. The potential uses and scope of this process have not been evaluated, but several applications become immediately apparent. For example, the study of welding effects on reactive materials without the masking effect of gas contamination will make possible a more accurate and complete determination of the effects of welding. This type of study should lead to a better understanding of the requirements for joining several of the new materials, such as zirconium, titanium, etc., and advance the science of welding.

*Acknowledgment*

The author wishes to express his appreciation to H. W. LeFevere and J. T. Russell of the Nuclear Physics Operation, Hanford Laboratories, for their assistance and advice on the electronic problems associated with this process development. Also, the Physical Metallurgy Operation, Hanford Laboratories, was very helpful in loaning a high-voltage supply for the early development period of this process.

# THE QUALITY OF OXYGEN-CUT SURFACE

BY H. CHRISTOPH

The German Standard DIN 2310 recognizes four factors to be measured in estimating the quality of oxygen-cut surfaces in steel plates 3/8 to 4 in. thick.

1. The roughness of the surface usually is measured in the Johannsen apparatus. A needle is passed over the surface for a distance of 3/8 in. The needle is connected by a lever to a dial. A reading is taken every 0.002 in. The difference between maximum and minimum reading is the roughness. It averages 60 to 70 microns for cuts made at optimum conditions. As low as 40 microns can be attained in exceptionally smooth cuts. If the roughness exceeds 100 microns, the cut no longer has neat appearance.

2. The planeness of the cut from top to bottom is important. The cut should not be more than 0.004 in. out of plane from top to bottom. That is, it should not exceed the maximum allowed roughness.

3. The rounding of the top edge should not exceed a radius in inches of 0.004 to 0.003T, where T = plate thickness in inches.

4. The angle of the draglines should not exceed: $\sin \alpha = 0.01 + 2/25.4T$, where $x$ is in degrees. The permissible angle drops, according to this relation, from 12 deg for 3/8-in. plate to 5 deg for 1-in. plates, and to 2 deg for 4-in. plates. The angle is measured by means of a protractor. The average width of kerf is $0.017 + 0.08$ in.

Abstract by **Gerard E. Claussen**, of "Einfluss der Schneidbedingungen auf die Oberflachenbeschaffenheit in wirtschaftlicher Hinsich," published in *Schweissen und Schneiden* 8:220–237 (July 1956).
Dr. Claussen is associated with the Development Laboratories, Linde Company, Newark, N. J.

# FATIGUE FAILURES IN FATIGUE MACHINES

*Limited information available indicates that welded flexural members which are subjected to many millions of cycles of loading may fail at relatively-low maximum nominal stresses*

BY W. H. MUNSE

## Introduction

During recent years, structural research engineers have attempted to extend their laboratory fatigue tests to larger and larger members, particularly in the case of flexural members such as beams and girders. In a few instances, it has been possible to test relatively large members *but*, because of equipment limitations, most flexural testing has been done on beams less than 16 in. deep.

Another source of information concerning the fatigue strength of large members would be service failures. Records and data from fatigue failures of actual structures, when such failures occur, will provide more realistic information than the laboratory fatigue studies if sufficient load, stress and cycle data can be obtained concerning the structures. However, these data are seldom available and generally result only after many years of operation of the structures. By this time the designs, details, materials and methods of fabrication in current use for similar applications or structures may differ markedly from those used for the original structure. Nevertheless, a great deal can be learned about fatigue resistance from a careful study and analysis of such structural failures.

Although not strictly field failures, the recent fatigue cracks which have been encountered in the large-scale fatigue testing machines at the University of Illinois provide data on the behavior of large flexural members that have been subjected to repeated loads. This is admittedly a rather crude test but, since reasonable estimates can be made of the maximum and average loads on the members, and the number of load applications, a good deal can be learned from an analysis of these failures.

## Description of Structures

Since 1935 eight large-scale fatigue testing machines have been built at the University of Illinois for use in large-scale structural testing. A list of these machines and their capacities is given in the following tabulation:

| *Machine no.* | *Year built* | *Capacity, lb* |
|---|---|---|
| 1 and 2 | 1935 | 200,000 |
| 3 and 4 | 1938 | 50,000 |
| 5 and 6 | 1940 | 200,000 |
| 8 and 9 | 1944 | 50,000 |

The failures to be discussed herein occurred in the 200,000-lb machines (Nos. 5 and 6) built in 1940. Failures were also found in Nos. 1 and 2 during the first few years of their operation. However, no data are available concerning these failures.

Machines 5 and 6 are shown in Fig. 1. These lever type machines are capable of producing test loads of 200,000 lb in either tension or compression at a rate of 180 cpm. Moreover, either the maximum or minimum load can be varied independently of the other so as to produce any desired cycle, including a complete reversal, a partial reversal or a pulsating load having any desired relation between the minimum and maximum.

Although most parts for the machines were fabricated in the laboratory shop, the principal beams, consisting of 24-in. standard I-beams with web plates welded in position to increase the section to a 6-in. thickness at the columns, were made in the shops of a large structural-steel fabricator. The results of this fabrication are readily visible in Fig. 1. Each web plate was welded to the beam with fillet welds on the ends and groove welds at the upper and lower edges (upper and lower flanges). The fillet welds were elongated and then their surface ground smooth to provide a gradual transition at the change in web section.

## Description of Failures

Over a period of several years, a num-

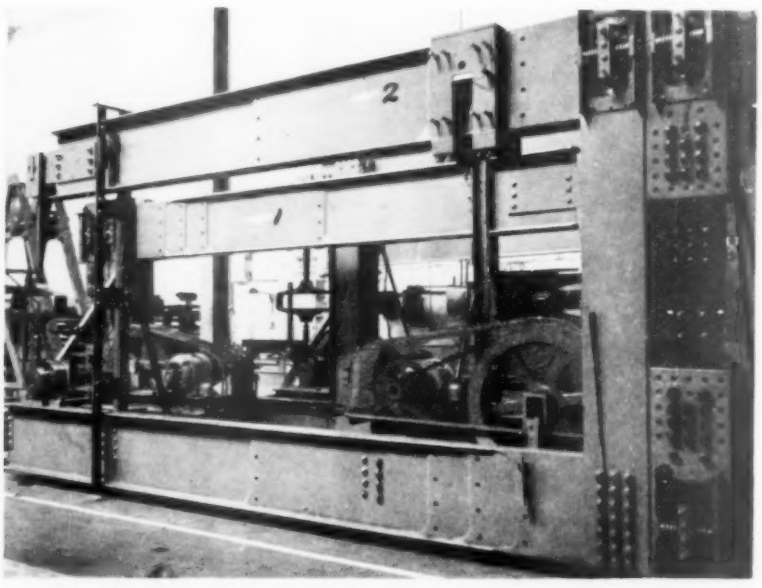



Fig. 1 200,000-lb fatigue testing machine

W. H. Munse is Research Professor of Civil Engineering, University of Illinois, Urbana, Ill.

ber of fatigue cracks have been found in the walking beams of both Machines 5 and 6. The records and data on these cracks are limited, but what little information is available can be used to make a number of rather interesting observations.

All of the fatigue cracks seemed to initiate at the junction of the web or web plates and the flanges of the beams and then propagated either into the web and flange or, in a few instances, along the flange. One of the first such cracks was found in Machine 5 in 1950 and occurred at the point marked "1" in Fig. 1. This crack propagated from the upper web-flange junction to a point about one-half of the way down the web and also across the flange before it was noticed. To repair the member, the crack was chipped out, the member preheated, and the section rewelded with low-hydrogen electrodes. After the weld had cooled, it was ground flush with the surface of the member. Further strengthening was provided at a later date by the addition of long cover plates to both the top and bottom flange.

In August 1951, a similar fatigue crack was observed in the upper beam of Machine 6. This crack, identified at position "2" in Fig. 1, was repaired in the same manner as the crack in Machine 5 and described above.

The next group of cracks to be observed is shown in Fig. 2. Here it can be seen that the cracks were vertical in the upper beam and horizontal in the lower beam; the length and location of the vertical cracks can be seen in Fig. 3 and the large horizontal crack in Fig. 4. Because of the use of a periodic inspection procedure, the cracks were noted before they had propagated to any great extent and repairs could easily be made.

The latest group of fatigue cracks to be found in the machines were noted during the summer of 1955. However, the rate of propagation of these cracks was very low and, as a result, repairs were not required until December 1955. By this time the crack in the top of the beam had extended through the flange and cover plate and was rapidly approaching complete failure.

For all of the initial large fatigue cracks, it was considered desirable to dismantle the testing machine for the chipping and welding operations. However, for the 1955 cracks an air-carbon electrode cutting torch was used to gouge out the crack without dismantling the machine—a much safer, simpler and faster operation than the chipping used in the previous instances. The member was then rewelded in the same manner as were the previous cracks, the weld ground flush, and the machine back in operation within two days.

## Analysis and Discussion of Failures

(a) *Maximum Stresses:* The 200,000-lb limiting capacity of the fatigue machines corresponds to the application of a load of 14,400 lb at the drive shaft of the machine. With this as the limiting load at the end of the walking beams, the maximum applied moment can be computed for each of the fracture locations. However, this will provide a maximum value of moment and not the average or typical moment to which the members were subjected.

In the case of the 1951 and 1952

Fig. 2 Fatigue cracks in 200,000-lb fatigue machine, No. 6 elevation of south face

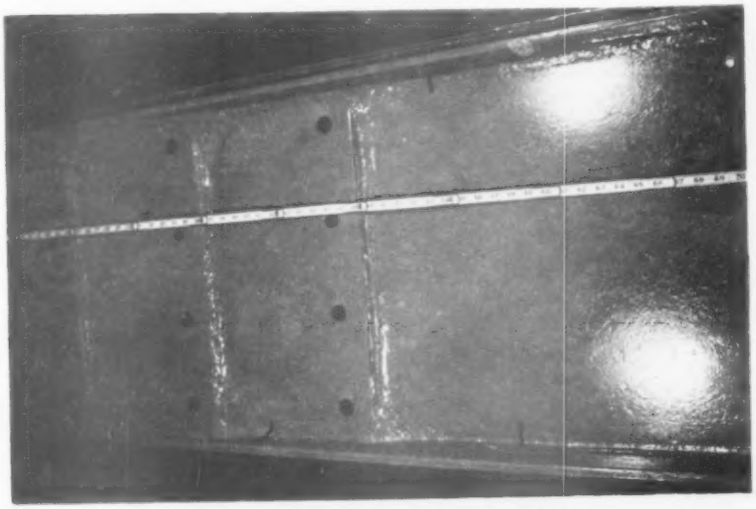


Fig. 3 Cracks in south face of upper beam of machine No. 6

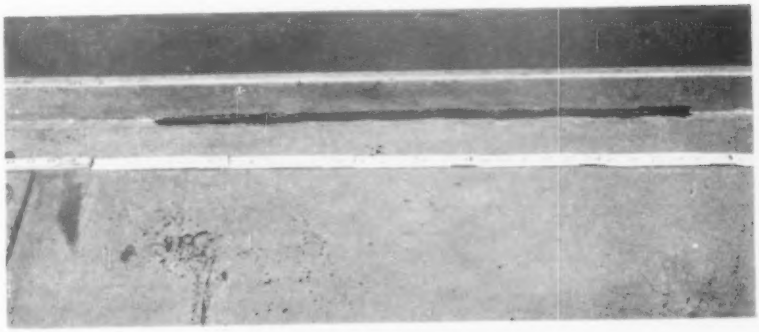


Fig. 4 Horizontal crack in weld of base beam of machine No. 6

failures, it was found that the cracks occurred at a distance of 141½ in. and 141 in., respectively, from the bearing through which the load is applied. Then, at maximum load, the moment at the crack position would be approximately 2,030,000 in.-lb; the moment of inertia at the section is found to be 3418 in.⁴. With these data, and using the relationship $s = \frac{Mc}{I}$, one finds that the maximum nominal stress was approximately 7150 psi at the *maximum load capacity* of the machines.

(b) *Number of Cycles:* The first failure in Machine No. 5 occurred when the equipment was 11 years old. Although an accurate record is not available, it is estimated that the machines had probably been in operation about 50% of the time. Then, with a speed of 180 rpm or about 250,000 cycles per day, a total of 500,000,000 cycles of loading may have been realized during the 11-yr period. This includes tensile and compressive loadings as well as reversals of load, all of various magnitudes.

(c) *Magnitude of Applied Stresses:* As noted previously, the maximum load capacity of the machines produced a nominal maximum stress of approximately 7150 psi at the first failure sections. However, in general, the applied loads have been below the maximum capacity and, as a result, the nominal stresses have been less than the 7150 psi maximum computed at the failure section.

It is estimated that the maximum test loads were generally of the order of 150,000 lb in tests on a tensile stress cycle. This is three-quarters the capacity of the equipment and equivalent to a maximum nominal stress of about 5360 psi at the location of the failures. For the tests conducted with a reversal of load, it is estimated that the loads were generally about ±100,000 lb, or the maximum nominal stresses about ±3580 psi. Thus, the magnitude of the typical test stresses would be about as follows:

| *Type of Cycle* | *Load, lb* | *Stress cycle, psi* |
|---|---|---|
| Zero to tension | 0 to +150,000 | 0 to +5360 |
| Tension to compression | ±100,000 | ±3580 |
| Capacity of machine | 200,000 | 7150 |

(d) *Location of Failures:* It is of interest to note that the fatigue cracks did not always start at the points of greatest nominal stress and to speculate as to the reasons for this behavior. In both Machines 5 and 6, the first fatigue failures occurred at a point midway between the vertical fillet welds at which the change in beam section took place.

The edge of the second pair of web plates was located a distance of 171 in. from the bearing through which the load was applied to the walking beam. At the maximum load capacity of the machines, the maximum nominal stress at this section would be 8650 psi, a value considerably greater than the 7150 psi noted above. In addition, the change in section at the edge of the second web plate would be expected to provide a stress concentration and a resulting increase in the nominal stress. Nevertheless, the failures generally initiated at the section at which the lower nominal stress existed (midway between the edge of the first and second web plates).

On the basis of the information available, it is suggested that two welding factors may have been responsible, at least in part, for the behavior observed, the location of the fractures and the fact that failures occurred at low nominal stresses. The first factor is the residual stress in the welds. This stress would probably be a maximum at the position at which the cracks initiated and, in this case, since a great many cycles of loading were applied, may have had a marked effect on the behavior. The second possible factor is the existence of thermal cracks in the welds which might serve to initiate the failures.

The small cracks marked in Fig. 3 and the long horizontal crack in Fig. 4 tend to indicate that there might be both transverse and longitudinal cracks in the welds which are propagated as a result of the moment and shear to which the beams are subjected.

## Conclusions

Because of the limited information available for the failures described herein it is difficult to draw many sound and justifiable conclusions. However, it can be seen that welded flexural members which are subjected to many millions of cycles of loading may fail at relatively-low maximum nominal stresses. This raises several questions concerning the cause of the failures which might well warrant further study.

1. Are there endurance limits for welded structures?
2. How great is the effect of residual welding stresses on the life of structures subjected to many millions of loadings?
3. Did microcracks or macrocracks in the welds initiate the failures of the welded beams?


**Welding Research Council Bulletin No. 38**

**Proof-Testing Pressure Vessels Designed for Internal Pressure**

**by R. W. Schneider, Travelers Indemnity Co.**

This Bulletin of 8 pages was issued by the Council in July 1957. This paper considers the significance of the data obtained from a proof test so that it may be properly interpreted and correctly applied when a vessel falls outside the scope of the Code.

Price—$1.00. Order single copies from American Welding Society, 33 West 39th Street, New York 17, N. Y.

# A HIGH-SPEED DILATOMETER DESIGNED FOR WELDING RESEARCH

*Design and operation of a high-speed dilatometer capable of duplicating the rapid heating rates and high temperatures which prevail in the heat-affected zone of a weld are discussed by the author*

BY E. C. NELSON

ABSTRACT. This paper describes the design and operation of a high-speed dilatometer capable of duplicating the rapid heating rates and high temperatures which are encountered in the heat-affected zone of a weld.

A continuous cooling transformation diagram for a low-carbon high-alloy steel is reported together with alternative methods of presenting such data.

## Introduction

Many of the physical measurement techniques which have been successful in determining equilibrium phase boundaries in metallic systems have been extended to investigate sub-equilibrium transformation phenomena. Of these methods, dilatometric analysis is especially attractive for investigating subcritical transformations in steels because of the practical significance of the volume expansion data which are obtained in addition to the primary transformation data.

A high-speed dilatometer is a device designed to measure, under conditions of continuous heat extraction from a steel specimen, the change in length resulting from the change in volume associated with the transformation from the face-centered cubic to the body-centered cubic phase. Thus, it differs from the usual dilatometer only in that the measurements are to be made continuously and at high speed. However, in a dilatometer designed to operate under equilibrium or near-equilibrium conditions, the length of the specimen and the characteristics of the dilation measuring equipment can be chosen to provide a high degree of sensitivity. The slow rate of heating and cooling also permits the use of precision pyrometry methods to measure temperature. The measurement of dilation and temperature under conditions of rapid cooling not only requires automatic measuring devices but also imposes certain physical limitations on the specimen, which in turn determine the sensitivity requirements of the measuring equipment.

A description of a high-speed dilatometer has been published[1] as well as a later description of modifications to the original apparatus[2]. The RPI high-speed dilatometer was designed to operate not only at high cooling rates but also to reproduce the high heating rates and high temperatures which are encountered in the heat-affected zone of a weld.

## Description of Equipment

The precise measurement of rapid changes in the length of a dilatometer specimen requires an extensometer which combines sensitivity with low inertia and negligible friction. Because the electronic micrometer described in Reference 1 was not commercially available, an optical-grating gage was adopted.

The optical-grating extensometer uses a mechanical motion to modulate the intensity of a beam of light.[3] The motion can be translated into an electric signal by means of a photoelectric cell. The simplest form of this gage would be an optical slit or shutter whose aperture is varied by the movement being studied. The percentage change in the amount of light transmitted through the slit is equal to the percentage change in slit width. If the maximum width of the slit is accurately known, the absolute values of the strains can be computed.

The optical-grating extensometer is a logical extension of the variable-aperture principle. In this gage, a multitude of slits is formed by two parallel gratings which are ruled in alternate, transparent and opaque bands of equal widths. When one grating is held stationary and movement is imparted to the other grating in a direction perpendicular to the rulings, the amount of light transmitted through the two gratings will be a direct function of the displacement. The output from a phototube measuring the intensity of the light transmitted through the gratings, when plotted against the displacement of the gratings, will assume a cyclic saw-tooth form; each straight line segment corresponding to the aperture of the slits, as shown in Fig. 1. Each time the extensometer displacement exceeds the slit width, the output is self-calibrated independently of the associated amplifying and recording devices.[3]

This type of gage is capable of high sensitivity, and its speed of response is limited only by the inertia and friction of its moving parts. The minimum slit width is limited by diffraction effects; however, the practical difficulties encountered in ruling such a grating make the actual minimum slit width coarser than that of a diffraction grating.

The gratings used in these extensometers must be precisely ruled in alternate, transparent and opaque bands of equal width. Such gratings are commercially available at reasonable cost from suppliers of photo-engraving equipment. Since photo-engraving screen is ruled on a heavy glass plate, it in itself is not suitable for incorporation into a gage. The gratings actually used in the gage are photographic copies of the engraving screen, made on thin glass photographic plate.

The gratings used in this dilatometer were the finest commercially available at the time of its construction and have an aperture of 0.0025 in. This distance is much less than the total contraction of the specimen, so the dilation record will "fold" itself several times during the taking of a record, as indicated in Fig. 2. This folding is equivalent to multiplying the width of an oscillograph chart and greatly increases the possible precision obtainable with a given chart width. The actual precision obtained with this gage and its associated amplifying and recording equipment was three microinches.

The complete high-speed dilatometer

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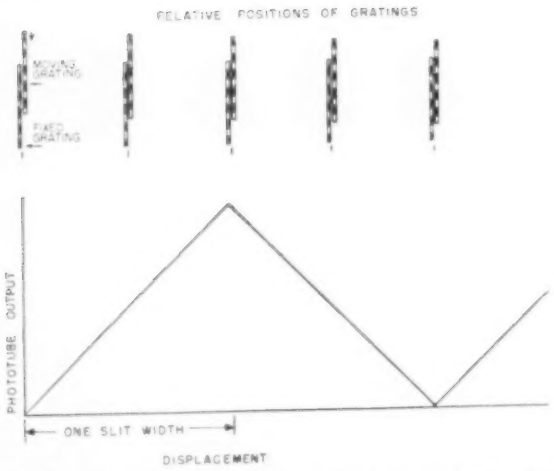


Fig. 1 The principle of the optical-grating extensometer

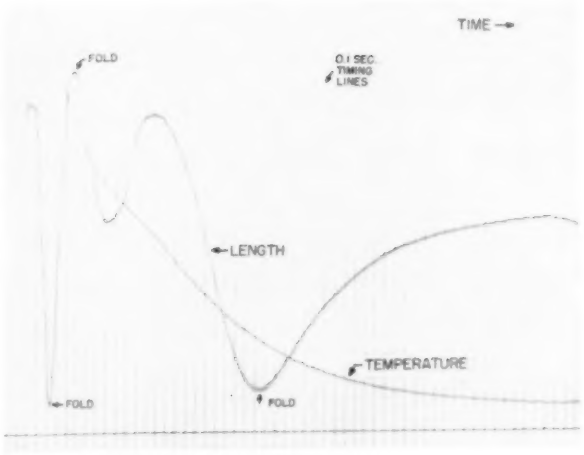


Fig. 2 Typical oscillograph record

is shown, in section, in Fig 3. The specimen is a hollow cylinder, $\frac{3}{8}$ in. ID, $\frac{13}{32}$ in. OD and either 0.5 or 0.7 in. in length, which rests on a quartz tube whose top is ground to the shape of the specimen to provide a firm seat.

At the top of the specimen is a quartz wafer which has been ground to provide a closely-fitting cap. A quartz rod projects through the wafer, specimen and quartz tube, and is secured at its top to the wafer by a ball-and-socket joint.

The quartz tube and rod together provide a means of measuring length changes in the specimen. Any contraction or expansion of the specimen will cause a relative motion between the quartz rod and tube. This relative motion is measured by the optical gage.

The two component gratings of the gage are mounted on an optical axis which intersects the direction of motion of the specimen at right angles. One grating is mounted on a threaded cap at the end of the slit system. This grating can be rotated about the optical axis to secure alignment of its rulings with those of the other grating, but its position with respect to the quartz pedestal tube is rigidly fixed by the dilatometer assembly.

The other grating is held in a yoke at the bottom of the quartz feeler rod. Thus, as the specimen expands, this grating is moved upwards across the face of the fixed grating, and the light beam along the optical axis is modulated accordingly. A spring attached to the bottom of the quartz feeler rod maintains sufficient tension to enable the moving parts of the gaging system to follow accurately the movement of the specimen.

The surfaces of the fixed and moving gratings must be held in intimate contact with each other without introducing sufficient friction to slow the speed of response. This is accomplished by floating one grating over the other on a film of clear mineral oil. The sliding friction is negligible, and the surface tension of the oil holds the grating surfaces precisely parallel without restraining their movement.

The light for the gage is furnished by a 50-cp automobile headlight bulb and a condensing lens external to the dilatometer case. The light beam is collimated by a pair of slits and the modulated beam is measured by a Type 929 high-vacuum phototube. The entire lower portion of the dilatometer is cased with sheet metal to avoid errors from stray light sources.

The dilatometer was originally designed to hold the quartz pedestal tube rigidly fixed with respect to the stationary grating. Difficulties with dilatometer curves wherein the curve folded at the beginning of, or during a transformation, necessitated some provision for shifting the gratings with respect to each other so that the transformations could be registered along linear portions of the saw-tooth curve, shown previously in Fig. 1. This gage-reference shifting was provided by placing a rigid bar across the top of the receptacle which holds the bottom of the quartz pedestal tube. When the thumb-bolts on either end of the bar are tightened the bar shifts the position of the quartz pedestal tube with respect to the fixed grating by flexing the sheet metal on which the pedestal receptacle is mounted.

The specimen size and shape represent a compromise between several conflicting requirements. The longer the specimen, the less the sensitivity which is required of the dilation-measuring equipment. However, the longer the specimen the more difficult it is to secure uniform heating and cooling along its length. A large outside

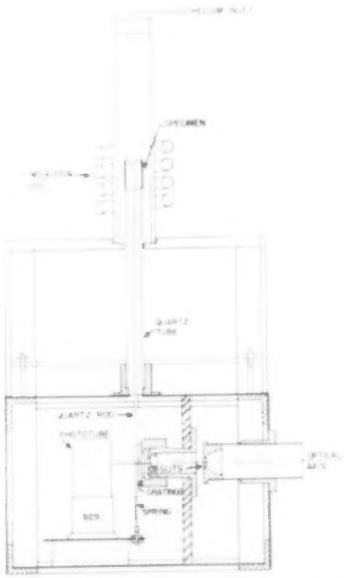


Fig. 3 Cross-sectional view of the high-speed dilatometer

diameter also tends to make quenching non-uniform.

A tubular rather than a solid specimen is necessary to obtain a reasonably uniform temperature distribution throughout the cross section being measured. The wall thickness should be as small as practical in order to minimize the temperature differential across the section of the specimen. The minimum thickness of the specimen is limited by machining difficulties and the danger of collapse of the specimen at high temperatures. Except at very-high cooling rates, the concentricity of the inside and outside surfaces is usually more important than the absolute value of the wall thickness, provided that the

latter is within certain reasonable limits.

The temperature of the specimen is measured by a 30-gage chromel-alumel thermocouple. One wire of the thermocouple pair is flash welded to the outside of the specimen; the other wire is flash welded to the inside of the specimen. The thermocouple signal is recorded by a Hathaway Type OE galvanometer mounted in a Hathaway Type 814-A oscillograph. This galvanometer has sufficient sensitivity (750 mm/ma/m) to require an attenuating resistance in series with the thermocouple. This resistance is adjusted to provide the maximum possible deflection of the thermocouple galvanometer. The external resistance of the circuit is varied from 65 to 100 ohms, which is large enough to render negligible the temperature variation in resistance of the heated portions of the thermocouple wires. The deflection sensitivity of the thermocouple circuit enables temperatures to be read to within 2.3° F.

The dilation signal is recorded with a Hathaway Type OA galvanometer having sensitivity of 50 mm/ma/in. The minute phototube current is amplified to the value required for full-scale deflection of this galvanometer by means of a d-c amplifier (Fig. 4). This amplifier is adapted from a circuit recommended for phototube measuring devices by the phototube manufacturer.[3] The output tube recommended in Reference 3 was a Type 6K6. This tube has remote cut-off characteristics which were found to affect seriously the linearity of the record. In the present apparatus one-half of a Type 6SN7 tube, which is a sharp cut-off double triode, is used for the output.

The gage signal in the amplifier output is superimposed on a large steady-state current. The steady-state current is neutralized by a current from a battery and rheostat placed across the output terminals.

The plate voltage for the 6SN7 tube is supplied by a carefully-regulated electronic power supply. All other plate and bias voltage are obtained from dry batteries. In spite of these precautions, the drifting characteristics, which are inherent in d-c amplifiers caused some difficulties. Stability was a particular problem at some of the slower cooling rates, which required from 5 to 10 min to complete the measurements. The inherent symmetry of the gaging method used, as indicated in Fig. 2, permitted the use of much data in spite of changes in amplification during the taking of the data.

Two methods of heating and cooling the specimen are provided to extend the usefulness of the dilatometer over a wide range of cooling rates. The heating and quenching system shown in Fig. 3 provides slow cooling rates for studying steels of high hardenability, but a sacrifice of fast heating rates. The specimen is contained within a stainless-steel tube of $^{3}/_{4}$ in. OD and $^{3}/_{8}$-in. wall thickness. An induction coil is fitted around the outside of this tube and the specimen is heated indirectly by radiation from the tube. An atmosphere of helium gas is maintained within the tube while the specimen is being heated, and quenching is done by a sudden increase in the flow of helium. The thermal inertia of the stainless-steel tube permits the study of steels at cooling rates as slow as 10° F/

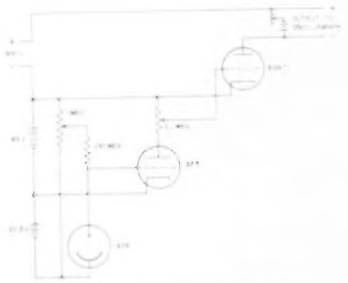

Fig. 4 Phototube amplifier circuit

sec. Still slower cooling rates can be obtained by wrapping iron wire around the tube to increase its thermal capacity or by building a small electric resistance furnace around the pipe.

The heating and quenching device used to obtain rapid cooling rates is shown in Fig. 5. It replaces the pipe shown in Fig. 3. The specimen is heated by a loosely-coupled, water-cooled induction coil which is perforated

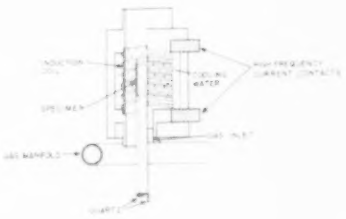

Fig. 5 High-frequency induction coil and gas quenching fixture for the high-speed dilatometer

by a helical pattern of 0.028-in. diam holes. The coil is mounted in a polystyrene case acting as a gas chamber for the quenching gas, which is admitted to the chamber through a gas manifold at the bottom. Provision is made for a continuously-flowing protective gas atmosphere to be introduced through a tightly-fitting cap which is not shown in the drawing. The specimen is heated by energizing the induction coil with a high-frequency current. When the desired austenitizing conditions have been fulfilled, the specimen is instantaneously quenched by turning the power off and turning on a solenoid valve which admits helium to the quenching gas manifold. Both of these operations are controlled by a single switch, so the time lag between the heating and quenching cycles is less than 0.1 sec.

The heating coil of this device is the secondary coil of an autotransformer. The power available for heating the specimen is greatly reduced by induc-

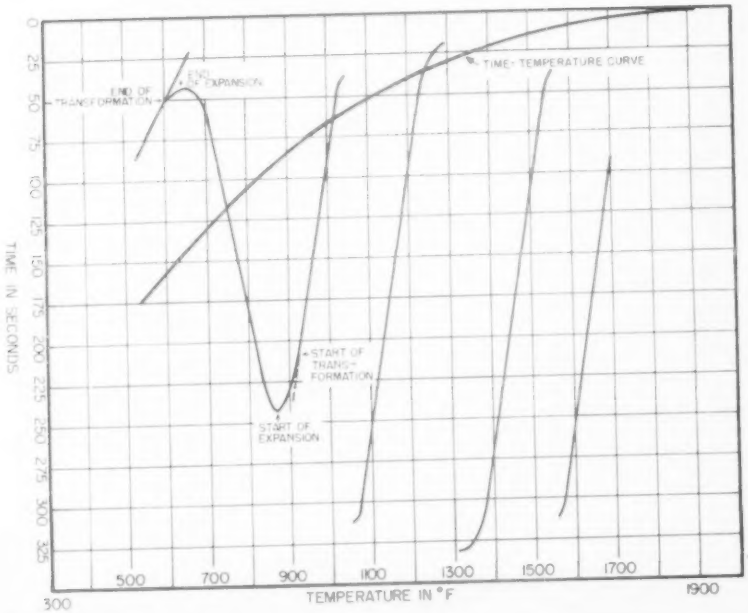


Fig. 6 Typical dilation curve

tive losses in the primary coil. This fact is made use of in maintaining precise control of the temperature reached by the specimen. An iron slug placed in the field of the primary coil acts as a parasitic inductance. The precise orientation of this slug within the primary coil provides smooth and accurate control over the power available at the secondary coil, and hence over the temperature of the specimen. The desired austenitizing temperature can be maintained to within 5° F for long periods of time by the proper manipulation of the iron slug.

The specimen can be heated to its melting point in less than 1 sec with the maximum power applied to the induction coil. A heating time of 10–20 sec to reach the austenitizing temperature is necessary to obtain uniform heating of the specimen surface. The fastest quenching speed for usable data is approximately 1800° F/sec.

### Protection of Specimens

The principal problem in the operation of the dilatometer is the protection of the thin specimens against decarburization. The helium atmosphere alone does not protect the specimens sufficiently. Previous experience[1] has shown that a copper plate affords excellent protection to the specimen without affecting its dilation behavior. Specimens protected by flash plating in a cyanide copper plating solution and then copper plating to several thousandths of an inch plate thickness in an acid-sulfate bath gave usable data at temperatures up to 1900° F. Higher quenching temperatures require a replacement for the copper, which melts at 1981° F. A survey of electroplating information did not disclose any metal having satisfactory plating characteristics which combined a high melting point with a low hot-working temperature. The latter criterion is necessary because the plated metal must not restrict the specimen while it is transforming. Because of the failure of platable high-melting metals to fulfill this latter requirement, soft metals which were liquid at the maximum specimen temperatures were used to protect the specimens.

Copper will not wet steel in a commercially-pure helium atmosphere. It was found that a tin plate would form a bond between liquid copper and steel at high temperatures and that the resultant bronze, when solidified, did not interfere with the dilation characteristics of the steel. It was necessary to reduce the length of the specimens from 0.7 to 0.5 in. so that the surface tension of the liquid would balance gravitational forces and full protection could be secured. A liquid bronze plate will provide satisfactory protection up to 2100° F. Above this temperature the liquid is highly reactive and will destroy the thermocouples.

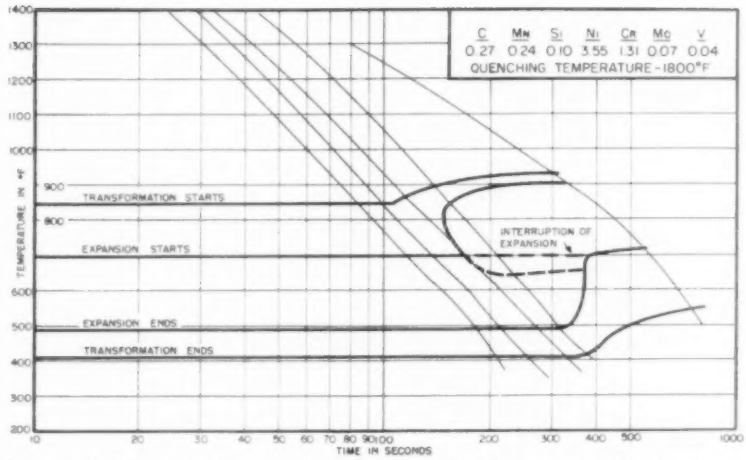


Fig. 7 Continuous cooling transformation diagram for a low-carbon high-alloy steel cooled from 1800° F

A suitable plate for protecting specimens in the temperature range of 2200–2300° F consists of a copper flash plate in a cyanide bath followed by 0.00075-in. silver from a cyanide bath and finally 0.001 in. of copper from a cyanide bath. The thickness of the various layers must be carefully controlled to prevent the alloy from becoming too fluid. The performance of the alloy plate is improved by homogenizing and sealing it to the steel surface by dipping the plated specimens in molten silver-brazing flux.

Molybdenum sulfide can be used to protect specimens at all temperatures above the melting point of copper, but its use is restricted to temperatures above 2300° F because of certain undesirable properties.

Molybdenum sulfide is applied to the specimens as a paint made by mixing the sulfide powder with a mineral oil vehicle. The thickness of the coating is a critical variable. Too thick a coating will restrict the movement of the specimen, while too thin a coating will not prevent decarburization. The sulfide is chemically active at these temperatures and attacks the quartz fixtures as well as the thermocouple wires. Thicker thermocouple wires (28 gage) are used at temperatures in excess of 2300° F to solve this problem. The thicker wires, however, interfere with the movement of the specimen and lower the quality of the data.

The deterioration of the quartz is most undesirable. Unfortunately, it undergoes thermal deterioration at temperatures in excess of 2000° F and so must be regarded as an expendable

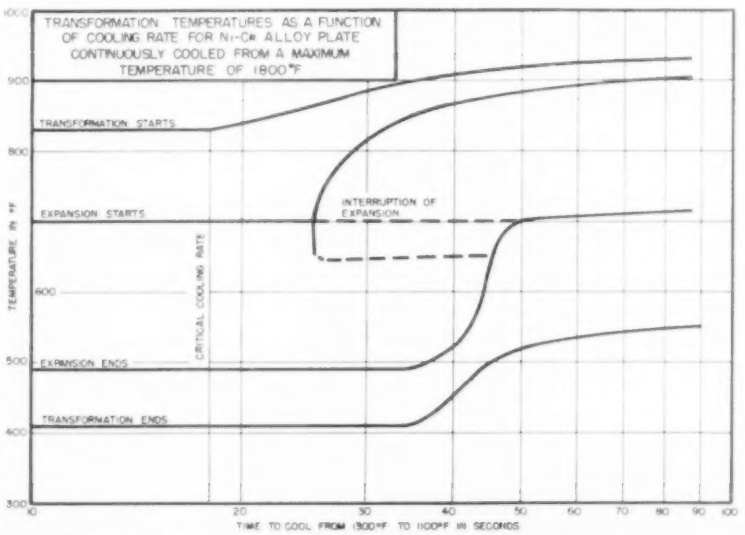
TRANSFORMATION TEMPERATURES AS A FUNCTION OF COOLING RATE FOR Ni-Cr ALLOY PLATE CONTINUOUSLY COOLED FROM A MAXIMUM TEMPERATURE OF 1800°F
TRANSFORMATION STARTS
EXPANSION STARTS
INTERRUPTION OF EXPANSION
CRITICAL COOLING RATE
EXPANSION ENDS
TRANSFORMATION ENDS
TEMPERATURE IN °F
TIME TO COOL FROM 1300°F TO 1100°F IN SECONDS

Fig. 8 Transformation temperatures as a function of time to cool from 1300 to 1100° F

item for investigations at higher temperatures.

### Treatment of Data

The data recorded on the oscillograph record paper consist of two traces, both of which are registered as functions of time. One trace shows the instantaneous temperature of the specimen, the other its dilation (Fig. 2). The deflections of the temperature trace are converted into °F by means of a deflection-temperature calibration chart and are plotted against time from the beginning of the quench as shown in Fig. 6.

The values of the dilation of each 5-sec interval are read to the nearest $^1/_4$ mm and are plotted against the corresponding instantaneous temperature to give the dilation-temperature curve of Fig. 6. This curve consists of several parallel branches, caused by the folding of the curve by the grating extensometer.

The beginning of a transformation is indicated by the first departure of a branch of the curve from parallelism with the higher temperature branches. This is shortly followed by a reversal of the curve showing that the specimen is expanding. This expansion corresponds to the major portion of the transformation. When the transformation is almost complete the curve passes through a maximum and again becomes linear, although with a different slope than before because the structure of the material is no longer austenite.

A complete description of the continuous-cooling transformation behavior of a steel is obtained from a set of a large number of dilatometer curves made at cooling rates ranging from faster than the critical cooling rate to the slowest obtainable cooling rate. These data are conveniently summarized in a continuous cooling transformation diagram. The type of the diagram used in Reference 1 is convenient to demonstrate general behavior of a steel and is desirable because of its general resemblance to the conventional "S" or "TTT" curve.

In making this type of diagram, the time-temperature curve for each dilation record is plotted on semi-logarithmic paper. Temperature is plotted on the linear ordinate and time is plotted on the logarithmic abscissa. The temperatures of the beginning of transformation, beginning of expansion, end of expansion and end of transformation for each dilation curve are then plotted on the corresponding time-temperature curve and an envelope curve is drawn through the respective points on the time-temperature curves. Such a curve is shown in Fig. 7, which shows the continuous cooling transformation behavior of a low-carbon high-alloy steel

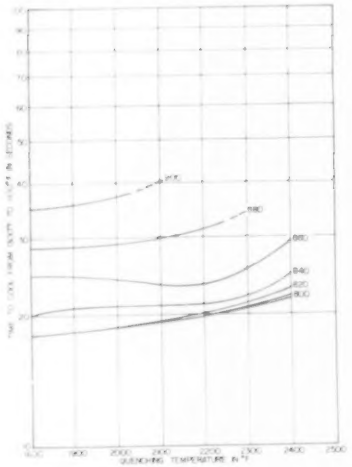

Fig. 9 Isotherms for the beginning of transformation as a function of austenitizing temperature

on cooling from 1800° F. Such a curve resembles the conventional S or TTT curve in general appearance, but the lines representing transformation to products other than martensite are displaced downward and to the right in comparison with the corresponding lines on the appropriate TTT curve. The dotted lines enclose a region where transformation has momentarily stopped. This is not a "split" transformation, but an effect of inhomogeneous banding in the steel.

Such a diagram shows directly the critical cooling rate and hence may be directly used for hardenability comparisons. The displacement of the non-martensitic transformation curves may be interpreted qualitatively to derive information concerning the relative effects of alloying elements. However, it is inconvenient to use the time-temperature curves on this type of diagram to calculate the location of transformations under cooling conditions encountered in a practical workpiece such as a weld. For the sake of clarity, most of the cooling curves are omitted from the final diagram and only the major time and temperature intervals are commonly included. Consequently, considerable interpolation of cooling curves is required. A more desirable type of diagram would show the transformation data in relation to some general criterion of cooling rate.

Numerous methods have been used to equate the cooling rates encountered in hardenability test specimens, such as the Jominy bar, to the cooling rates, encountered in practical workpieces, such as welds. The guiding principle of any such method is the assumption that austenite of a given composition will transform to the same products if its cooling rate at some sub-critical temperature is the same for various cooling cycles, even though the actual time-temperature curves for these various cycles vary within reasonable limits.

Two such criteria have attained widespread acceptance in weldability research: the cooling rate at 1300° F. and the time to cool from 1300 to 1100° F. The latter criterion was believed to be more desirable for use in presenting the data of this report. The measurement of instantaneous cooling rates from time-temperature curves is subject to a certain degree of human error. Also, the criterion of the slope during the 200° F interval just below the lower equilibrium critical temperature is more effective in insuring that correspondence between curves will be exact in the important sub-critical region.

The data of Fig. 7 are shown in Fig. 8 after replotting the transformation temperatures as a function of the time to cool from 1300 to 1100° F. This method of representation of these data permits the calculation of transformation temperatures from cooling rate information.

The curves of Figs. 6 and 7 apply to only one austenitizing temperature. Separate curves can be used to describe the effects of the austenitizing temperatures, but it is more satisfactory to represent the variation of transformation temperature as a function of austenitizing temperature with a transformation isotherm diagram. Such a diagram shows isotherms for the beginning or end of transformation plotted as functions of the time to cool from 1300 to 1100° F and the austenitizing temperature (Fig. 9). Such a transformation isotherm plot is effective in demonstrating the metallurgical effects of various quenching temperatures.


*Acknowledgments*

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# THE NATURE OF HIGH-TEMPERATURE BRAZING ALLOY—BASE METAL INTERFACE REACTIONS

*Microstructural and hardness characteristics analyzed at brazed joint interfaces, in the unaged, aged and superheated conditions, of combinations of five types of high-temperature base metals and three types of high-temperature brazing alloys*

BY W. FEDUSKA

## Introduction

Heat- and corrosion-resisting alloys are being used in increasing amounts as components in equipment operating at elevated temperatures. Such equipment includes jet engines, land gas turbines, steam turbines, nuclear reactors and heat exchangers. In assembling such components, numerous joining operations are required. Industries which produce these items are interested in simplifying these joining techniques so that sounder units may be produced at lower fabrication costs.

High-temperature alloy brazing is a joining method which may realize these desired advantages. By high-temperature alloy brazing, numerous parts may be joined in a single operation and the fabricated assembly would be essentially free from base-metal fusion and distortion, thereby eliminating the necessity of post-joining treatments.

Unfortunately, the insufficiency of technical knowledge related to high-temperature alloy brazing has prevented its immediate application to these problems. Therefore, a program was initiated whereby the fundamentals controlling brazed joint formation might be determined. The information obtained from this program might then be applied to actual brazing problems.

In this investigation, dealing with a single phase of the program, the microstructural and hardness characteristics of a variety of high-temperature brazing alloy-base metal interfaces have been evaluated. Since these microstructures reflect resultant products of diffusion reactions during brazing, this appraisal has led to a qualitative understanding of specific reactions which transpire during high-temperature brazing.

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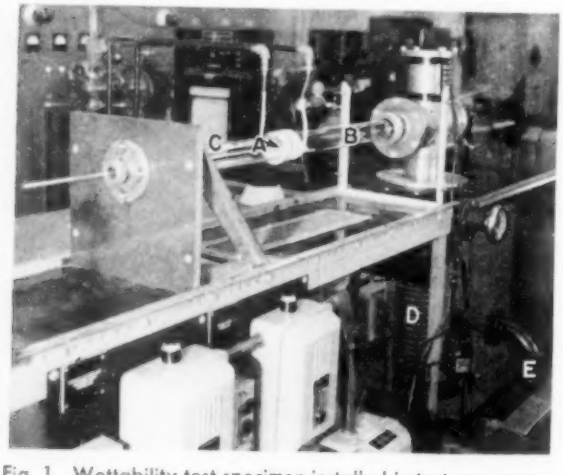


Fig. 1 Wettability test specimen installed in test apparatus

A—Wettability specimen
B—Vycor tube
C—Pt-Pt Rh thermocouple
D—MC-275-01 diffusion pump
E—MB-200 booster pump

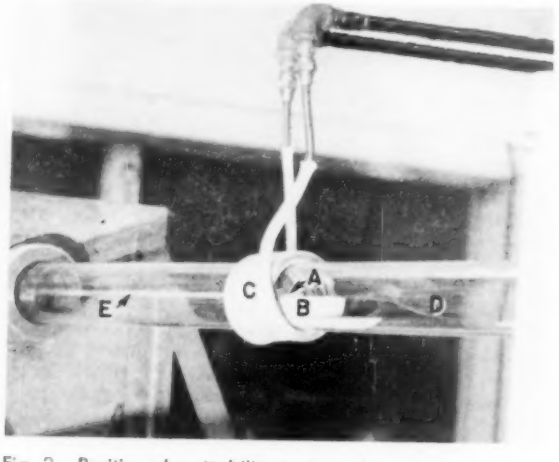


Fig. 2 Positioned wettability test specimen

A—Wettability specimen
B—Alundum holding fixture
C—Induction coil
D—Vycor tube
E—Pt-Pt Rh thermocouple

Table 1—Compositions and Treatment Temperatures of High-Temperature Base Metals and Brazing Alloys Used in the Wettability Tests

| *Base metals* | *Nominal composition* | | | | | | | | | | | | *100-hr aging temperature* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Type and/or designation* | *C* | *Mn* | *Si* | *Cr* | *Ni* | *Co* | *Mo* | *W* | *Nb+Ta* | *Ti* | *Al* | *Fe* | |
| AISI 410; martensitic stainless | 0.15 max | | | 11.5–13.5 | | | | | | | | Bal | None |
| AISI 347; austenitic stainless | 0.08 max | | | 17.0–19.0 | 9.0–13.0 | | | | 0.80 min | | | Bal | 1290° F |
| Iron-base, high-temperature alloy, titanium hardened | 0.03 | 0.8 | 0.8 | 13.5 | 26.0 | | 3.0 | | | 1.6 | 0.1 | Bal | 1290° F |
| Nickel-base, high-temperature alloy, titanium hardened | 0.04 | 0.7 | 0.3 | 15.0 | Bal | | | | 0.9 | 2.5 | 0.9 | 7.0 | 1470° F |
| Cobalt-base, high-temperature alloy | 0.10 | 1.5 | 0.7 | 20.0 | 10.0 | Bal | | 15.0 | | | | 1.0 | 1470° F |

| *Brazing alloys* | | *Composition* | | | | | | | | | | *Nominal brazing temperature* | *Superheat brazing temperature* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Number* | *Type* | *C* | *Mn* | *Si* | *Cr* | *Ni* | *B* | *S* | *P* | *Zr* | *Al* | *Fe* | | |
| 1 | Ni-Cr-Si-B-C | 0.76 | | 4.60 | 13.67 | Bal | 3.13 | | | | | 4.29 | 1970° F | 2060° F |
| 2 | Ni-Cr-Si | 0.17 | 0.81 | 9.91 | 18.95 | Bal | | 0.005 | 0.005 | 0.03 | 0.08 | 0.49 | 2120° F | 2210° F |
| 3 | Ni-Cr-Si | 0.03 | | 11.25 | 19.0 | Bal | | | | | | 1.1 | 2150° F | 2250° F |
| 4 | Ni-Si-B | | | 4.58 | | Bal | 2.89 | | | | | | 2070° F | 2150° F |

* Cooling rate from brazing temperature was about 165–210° F min down to 1470° F, below which the rate steadily decreased.

## Procedure

Wettability specimens, approximately $1^1/_8 \times 1^1/_8 \times {}^1/_8$ in., were prepared from each base metal. A $^3/_{16}$-in. diam $\times {}^1/_8$-in. deep thermocouple hole was drilled at the center of one edge of each sample, with the exception of the cobalt-base alloy which was too hard to drill. One face, $1^1/_8 \times 1^1/_8$ in., of each wettability sample was polished to a No. 1 metallographic paper finish and all other surfaces were mechanically cleaned of all traces of oxides.

Each sample was separately degreased as follows: washed with soap and warm water, dried with alcohol, degreased in trichloroethylene, rinsed with alcohol and dried. Dry brazing alloy powder (weighing 0.2500 gm) was centrally placed on the polished surface of the sample and the wettability specimen was then positioned on an alundum base, inside a vycor tube, at the location of an induction coil. A platinum-platinum rhodium thermocouple was inserted into the hole of the plate and the Vycor tube was sealed off, as shown in Figs. 1 and 2. Temperatures of the cobalt-base alloy samples were measured with an optical pyrometer. Thermocouple temperatures were also checked with an optical pyrometer during the test runs.

During testing, the wettability specimens were heated in vacuum (of about 0.05–0.07 micron) to the brazing temperature in about 2 min, held at brazing temperature for 1 min, and cooled to 392° F, in about 20 min before being removed from the apparatus. The brazed specimens cooled at a rate of 165–210° F minute down to 1470° F, below which the cooling rate decreased.

Brazed joint interface microstructures and hardnesses were examined for combinations of three types of high-temperature brazing alloys and six high-temperature alloys. These test combinations generally consisted of vacuum-brazed specimens in an unaged condition, in an aged condition (after 100 hr. in dry $H_2$ at a temperature simulating a maximum service temperature for the particular base metal) and in a superheated condition (vacuum-brazed at 120° F above the nominal brazing temperature). In Table 1, the compositions of the materials and the specific brazing conditions have been summarized. In these tests, AISI 410 was not aged, since little structural change was anticipated in heating this material for 100 hr at its maximum service temperature (about 1020° F. Brazing Alloy 2, with a superheat temperature of 2210° F, was substituted for Brazing Alloy 3 in the superheat tests, when superheating Brazing Alloy 3 to 2250° F in a vacuum produced excessive vaporization, probably of chromium, of that alloy.*

When the microstructural and hardness data had been obtained on these specimens, changes in the base metals and brazing alloys were noted and the reaction mechanisms were evaluated. All results were obtained with an excess of brazing alloy available for the diffusion reactions, a condition that might be expected to prevail at brazed-joint fillet regions.

## Results and Discussion

For simplicity, the separate results obtained by using each type of high-temperature brazing alloy have been detailed in Appendix I.

The results obtained by this investigation pertain to reactions which transpire at the resultant interface between the liquid brazing alloy and the solid base metal. This discussion assumes that some base-metal solution into the liquid brazing alloy may occur, by the formation, through diffusion, of interface, base-metal solid solutions which have melting temperature ranges within the limits of the brazing temperatures which were employed. When such a solid solution would dissolve, some "dilution" of the liquid brazing alloy would occur. However, the diffusion reactions which would prevail at the final liquid-solid interface would still depend upon diffusion of the elements of the original brazing-alloy composition, with regard to the particular base-metal composition.

### *Summary of Alloying Mechanisms During High-Temperature Brazing*

When a liquid brazing alloy contacts an oxide-free, solid base metal, a diffusion couple is created, due to the differences in concentration of elements in the components of the couple. If similar brazing cycles are used on various brazing alloys in producing unaged, aged and superheated brazed joint interfaces with various high-temperature alloys, the resultant structures become primarily dependent upon relative reactivities of the elements in the brazing-alloy composition, with regard to the base-metal composition (concentration gradients) and the relative sizes (atomic radii) of the atoms involved in the diffusion process.

Elements which were higher in concentration in the base metal than in

* At this same temperature, chromium has a higher vapor pressure than either the silicon or nickel of these brazing alloys.[3]

the brazing alloy may have begun diffusing toward the base-metal interface regions. Here, they would assist in forming complex solid-solution structures which were being produced by incipient volume diffusion of brazing-alloy elements into the base-metal grain lattices.

### *Austenitic-Type, High-Temperature Alloys*

Several diffusion reactions can occur during brazing of austenitic, high-temperature alloys. In the first type of reaction, interstitial atoms, or atoms of relatively-small atomic radii in the brazing alloy, diffuse into the base metal along grain boundary, "short-circuit" paths.[2] The interstitial element, carbon and the small boron atom will diffuse along the grain boundaries of nickel, iron and cobalt-base alloys. Silicon, of a relatively small atomic radius, only appears to diffuse extensively along base-metal grain boundaries of certain iron-base alloys. These diffusing elements may combine with base-metal elements either to form intermetallic compounds or superficially diffuse from the grain-boundary regions into the lattices of the adjoining grains to produce solid-solution compositions. Since grain-boundary diffusion requires relatively little activation energy,[3, 4] this reaction would primarily occur at low temperatures—as during heating to brazing temperature.

An "irrigation" effect[2] sometimes takes place when rapid grain-boundary diffusion occurs. By this mechanism, atoms of the brazing alloy, having diffused along grain boundaries, laterally migrate into the lattices of the base-metal grains, where intermetallic compounds may form and coalesce.

The second type of reaction consists of an incipient volume diffusion, whereby substitutional atoms of elements in the brazing alloy, having high concentration and relatively-large atomic radii, diffuse at a slower rate into the lattices of the base-metal grains along the entire interface region. This diffusion reaction* would occur at brazing temperature, where diffusion would not be so structure-sensitive.[2] Generally, this migration in the austenitic-base alloys involves the nickel, chromium and silicon of the brazing alloys. By these diffusion reactions, complex solid solutions form at the interface regions of the base metals.

Sometimes the complex solid solutions that form are unstable at lower temperatures, and decompose upon cooling from brazing temperature to form a solid solution of different composition in an eutectoid matrix. These unstable solid solutions have been observed in AISI 347; titanium-hard-

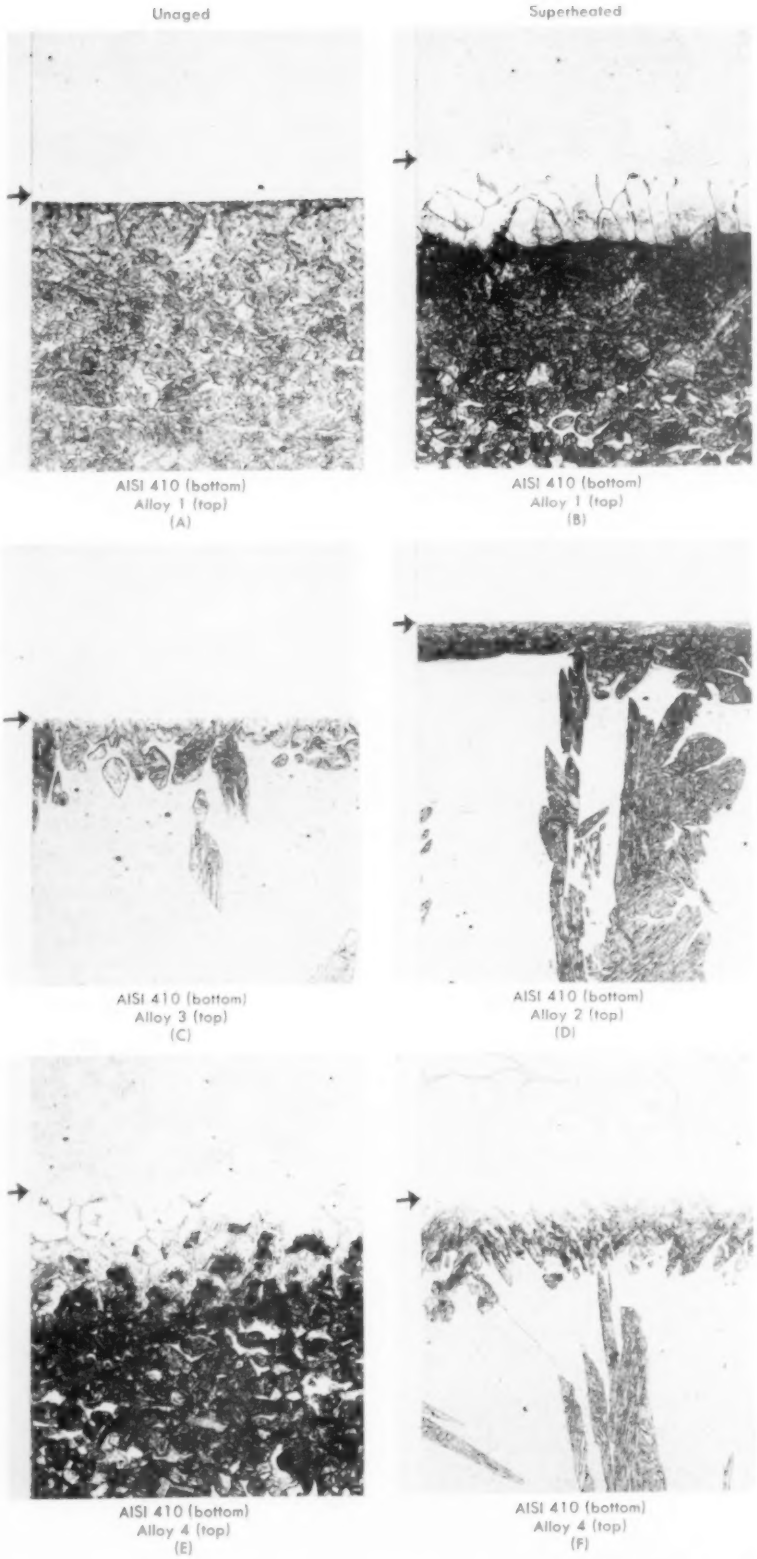


Fig. 3 Unaged and superheated microstructures produced by reactions of high-temperature brazing alloys with AISI 410. Arrows indicate the plane of the liquid-solid interface. Fry's etch. X 250

* Substitutional elements are generally believed to diffuse by a vacancy mechanism. Also, a "ring" diffusion mechanism is possible.[3, 4]

cmed, iron-base alloy; and cobalt-base alloy.

Small joint clearances would result in complete "absorption" of compound-forming diffuser elements such as C, B and Si by the base metal. Under this condition, the following ultimate brazing-alloy structures could be expected, for the brazing alloys investigated:

| *Brazing alloy* | *Ultimate structure in thin joint, after brazing* |
|---|---|
| 1 | Ni-Cr-Si-Fe-B-C—solid solution |
| 2,3 | Ni-Cr-Si—solid solution |
| 4 | Ni-Si-B—solid solution |

Therefore, the resultant brazing-alloy structures observed in brazed joints having small joint clearance may deviate from the microstructures reported herein, where an excess of brazing-alloy elements was used.

Gross volume diffusion appeared insignificant in these brazing tests as neither aging nor superheat produced marked changes in the "as-brazed" microstructures.

Several modifications of the general diffusion reactions appeared in the austenitic-alloy brazing tests. A titanium-carbide region, which formed at the joint interface during brazing of the titanium-hardened iron-base alloy with Brazing Alloy 1 (high carbon), retarded both boron-grain boundary diffusion and incipient volume diffusion of other brazing elements at the interface. Since the carbon diffusion (and TiC formation) would tend to fill grain-boundary vacancies and dislocation sites, and grain vacancies, interstices and dislocation regions, the number of "free flow paths" in the base metal would be reduced, making diffusion by other elements more difficult. Actually, the brazing-alloy structure was essentially unaltered in this test, except for the gross carbon migration. This effect also occurred during the superheat brazing test and was not modified by a 100-hr aging treatment at 1200° F.

### Martensitic Stainless Steel (AISI 410)

When martensitic stainless steel is brazed, only incipient volume diffusion reactions occur to produce complex solid solutions at the base-metal interface region. Sometimes these solid solutions are unstable and decompose upon cooling into solid solutions of different compositions in eutectoid matrices. A duplex martensite-ferrite structure was produced in the base metal after brazing above 2070° F, a temperature at which a two-phase austenite-ferrite region exists, and

Table 2—Hardness Variations Across High-Temperature-Alloy Brazed Joint Interfaces

Interface positions numbers are as follows:
1—2—resultant brazing alloy
3—4—brazing alloy at 0.002 and 0.001 in., respectively, from the interface
5—brazing alloy—base metal interface
6—7—base metal at 0.001 and 0.002 in., respectively, from the interface
8—13—a continuation of the base metal traverse at 0.001-in. intervals
14-15—unaffected base metal
Knoop hardness data obtained at 0.1-kg load

*AISI 410, Alloy 1, superheated*

| *Position* | *KHN* |
|---|---|
| 1 | 317 |
| 2 | 259 |
| 3 | 290 |
| 4 | 336 |
| 5 | 702 |
| 6 | 769 |
| 7 | 672 |
| 8 | 672 |
| 9 | 506 |
| 14 | 347 |
| 15 | 336 |

*AISI 410, Alloy 3, unaged*

| *Position* | *KHN* |
|---|---|
| 1 | 206 |
| 2 | 211 |
| 3 | 208 |
| 4 | 211 |
| 5 | 123 |
| 6 | 347 |
| 7 | 222 |
| 8 | 188 |
| 14 | 326 |
| 15 | 336 |

*AISI 410, Alloy 2, superheated*

| *Position* | *KHN* |
|---|---|
| 1 | 175 |
| 2 | 175 |
| 3 | 175 |
| 4 | 179 |
| 5 | 358 |
| 6 | 547 |
| 7 | 228 |
| 8 | 161 |
| 9 | 168 |
| 10 | 161 |
| 14 | 317 |
| 15 | 453 |

*AISI 410, Alloy 4, superheated*

| *Position* | *KHN* | |
|---|---|---|
| 1 | 526 | |
| 2 | 547 | |
| 3 | 267 | |
| 4 | 470 | |
| 5 | 408 | |
| 6 | 307 | |
| 7 | 157 | |
| 8 | 183 | |
| 9 | 171 | |
| 10 | 233 | martensite |
| 11 | 274 | island |
| 12 | 326 | |
| 13 | 175 | |
| 14 | 148 | |
| 15 | 164 | |

*AISI 347, Alloy 3, unaged*

| *Position* | *KHN* |
|---|---|
| 1 | 157 |
| 2 | 164 |
| 3 | 157 |
| 4 | 151 |
| 5 | 201 |
| 6 | 171 |
| 7 | 179 |
| 14 | 161 |
| 15 | 157 |

*AISI 347, Alloy 2, superheated*

| *Position* | *KHN* |
|---|---|
| 1 | 216 |
| 2 | 228 |
| 3 | 201 |
| 4 | 211 |
| 5 | 216 |
| 6 | 211 |
| 7 | 233 |
| 8 | 233 |
| 14 | 196 |
| 15 | 183 |

*Titanium-hardened iron-base alloy Alloy 1, unaged*

| *Position* | *KHN* |
|---|---|
| 1 | 282 |
| 2 | 347 |
| 3 | 295 |
| 4 | 308 |
| 5 | 234 |
| 6 | 212 |
| 7 | 275 |
| 14 | 184 |
| 15 | 168 |

*Titanium-hardened iron-base alloy Alloy 1, aged*

| *Position* | *KHN* |
|---|---|
| 1 | 526 |
| 2 | 592 |
| 3 | 592 |
| 4 | 423 |
| 5 | 347 |
| 6 | 317 |
| 7 | 326 |
| 8 | 307 |
| 9 | 290 |
| 14 | 290 |
| 15 | 298 |

*(Table continued on page 66-s)*

Table 2 Hardness Variations Across High-Temperature-Alloy Brazed Joint Interfaces (continued from page 65-s)

*Titanium-hardened iron-base alloy, Alloy 3, unaged*

| Position | KHN |
|---|---|
| 1 | 197 |
| 2 | 217 |
| 3 | |
| 4 | 253 |
| 5 | 253 |
| 6 | 180 |
| 7 | 188 |
| 14 | 184 |
| 15 | 180 |

*Titanium-hardened iron-base alloy, Alloy 1, unaged*

| Position | KHN |
|---|---|
| 1 | 526 |
| 2 | 188 |
| 3 | 437 |
| 4 | 506 |
| 5 | 307 |
| 6 | 283 |
| 7 | 283 |
| 8 | 274 |
| 9 | 290 |
| 10 | 282 |
| 11 | 290 |
| 12 | 290 |
| 13 | 259 |
| 14 | 216 |
| 15 | 253 |

*Titanium-hardened nickel-base alloy, Alloy 2, superheated*

| Position | KHN |
|---|---|
| 1 | 307 |
| 2 | 370 |
| 3 | 216 |
| 4 | 246 |
| 5 | 259 |
| 6 | 240 |
| 7 | 290 |
| 8 | 347 |
| 9 | 336 |
| 14 | 336 |
| 15 | 336 |

*Cobalt-base alloy, Alloy 1, superheated*

| Position | KHN |
|---|---|
| 1 | 382 |
| 2 | 358 |
| 3 | 358 |
| 4 | 347 |
| 5 | 423 |
| 6 | 347 |
| 7 | 382 |
| 8 | 395 |
| 14 | 358 |
| 15 | 382 |

rapidly* cooling from brazing temperature. Diffusion of nickel into the base metal apparently promoted austenite formation in this interface region upon heating, with subsequent martensite formation upon rapidly cooling from brazing temperature.

### *Effect of Superheating on Brazing Alloy-Base Metal Interface Reactions*

Superheat, or increased brazing temperature above the liquidus of the brazing alloy, generally produced structures similar to those obtained by brazing at a nominal brazing temperature (120° F above the liquidus of the brazing alloy). However, the extent of these base metal-brazing alloy diffusion reactions was greater.

### *Effect of Aging on Brazed-Joint Interface Microstructure*

Generally, aging affected little change in the nature of the microstructures produced by the brazing reactions. However, aging promoted the general diffusion mechanisms. For example, aging, for 100 hr, increased the amount of grain-boundary product in AISI 347 brazed with Alloy 3. In the titanium-hardened iron-base alloy, brazed with Alloy 1, aging produced an increased amount of carbon diffusion at the interface.

* Brazed specimens were cooled at a rate of 165–210° F/minute down to 1470° F in all tests, below which the cooling rate decreased.

### *Hardness Variations Across Brazed-Joint Interfaces*

Hardness variations across brazed-joint interfaces reflected the extent of the diffusion reactions and the nature of the reaction products which formed during brazing. Relatively high brazing-alloy hardness (350-850 KHN) resulted when considerable carbon and/or boron and/or silicon had remained in the brazing alloy. Conversely, relatively low hardnesses (about 150 - 200 KHN) after reaction resulted when excess amounts of these brazing-alloy elements, beyond their solid solubilities in the resultant brazing-alloy "base" composition, had diffused into the base metal. Very high interface hardness values suggested a high concentration (pile-up) of the diffusing carbon, boron or silicon, at the interface region.

## Conclusions

An investigation of brazed-joint-interface microstructural and hardness characteristics has revealed the nature of high-temperature alloy brazing mechanisms.

1. Martensitic-type stainless steel (AISI 410)
   a. Incipient volume diffusion reactions generally predominated in brazing AISI 410 material.
      (1) Below 2070° F brazing temperature, restricted volume diffusion of brazing-alloy elements produced a complex solid solution at the joint interface region.
      (2) Carburization of the base metal occurred by interstitial diffusion, when the brazing alloy was high in carbon (as Alloy 1).
      (3) At about 2070° F, an unstable solid solution was formed in the interface base metal, which decomposed upon cooling from brazing temperature. The transformation produced a complex solid solution (Fe-Cr-Ni-Si) in an eutectoid matrix of complex solid solution and intermetallic compound (borocarbide or boride — depending upon the brazing-alloy composition).
      (4) At brazing temperatures of 2150° F and above, incipient volume diffusion of austenite-forming nickel produced an austenite interface structure which transformed to martensite on rapidly cooling from brazing temperature. A duplex base-metal structure, of martensitic islands in a ferritic matrix, was produced by heating the AISI 410 into a two-phase, austenite-ferrite region at these brazing temperatures, and rapidly cooling from brazing temperature.
2. Austenitic - type high-temperature alloys
   a. Grain boundary and incipient volume diffusion mechanisms predominated in the brazing reactions with gross volume diffusion relatively insignificant under the short-time brazing conditions.
      (1) Base-metal grain-boundary penetration primarily occurred during heating to brazing temperature while incipient volume diffusion occurred at brazing temperature.
      (2) Interstitial elements, (as carbon) and sometimes elements of relatively small atomic radii (boron and silicon) in

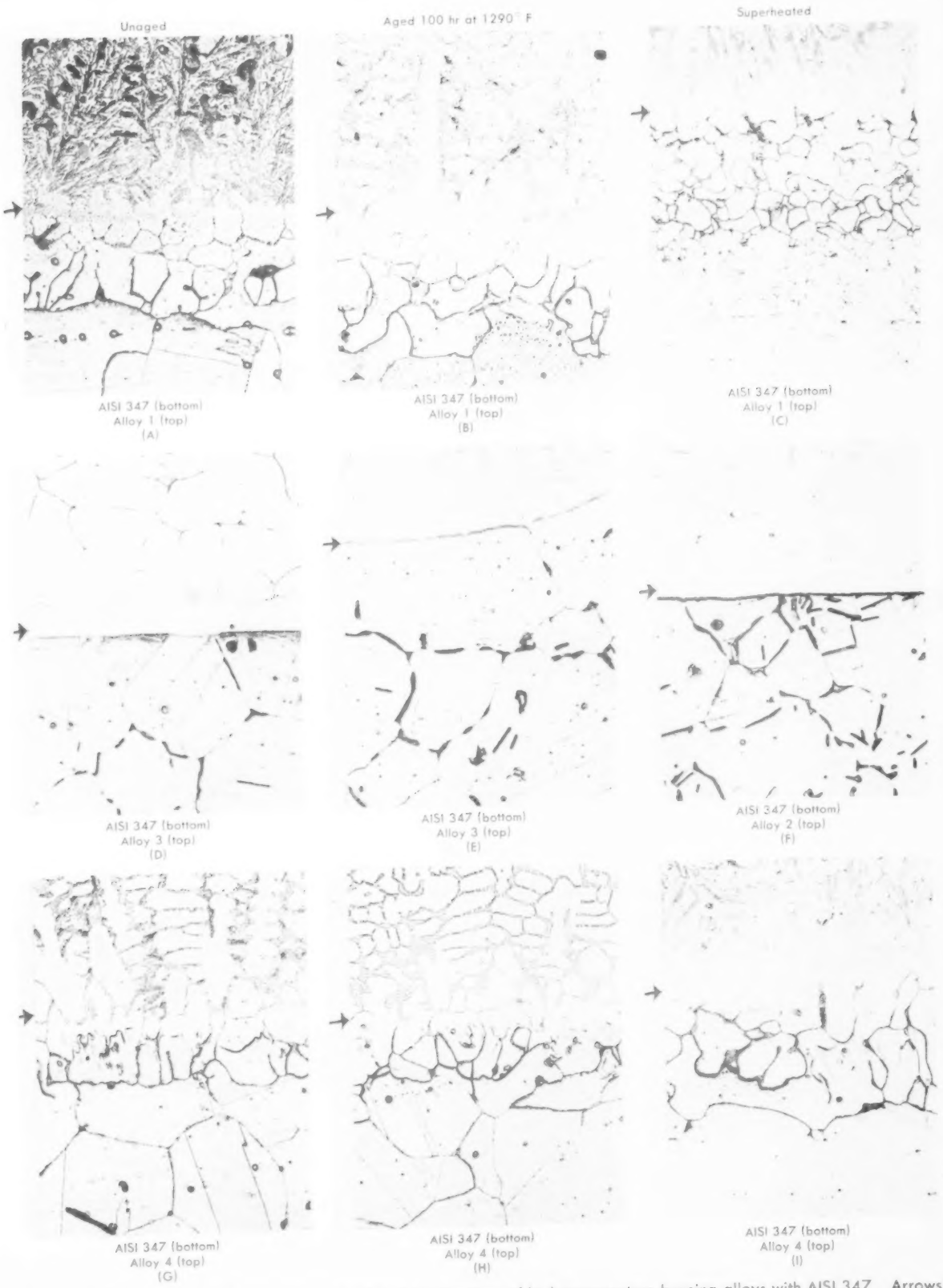


Fig. 4 Unaged and aged microstructures produced by reactions of high-temperature brazing alloys with AISI 347. Arrows indicate the plane of the liquid-solid interface. Fry's etch. X 250

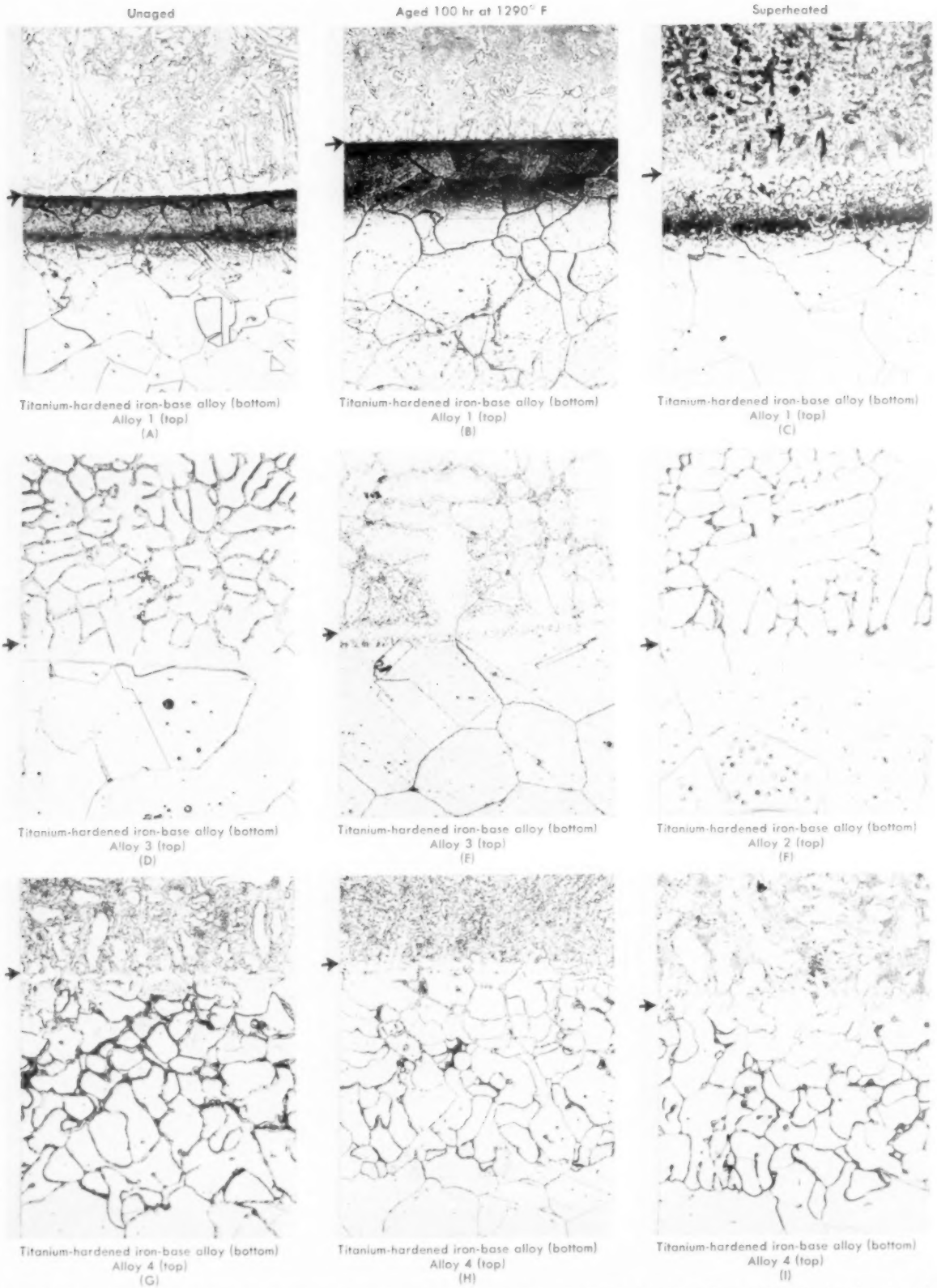


Fig. 5 Unaged and aged microstructures produced by reactions of high-temperature brazing alloys with a titanium-hardened, iron-base alloy. Arrows indicate the plane of the liquid-solid interface. Fry's etch. X 250

the brazing alloy diffused along base metal grain-boundary "short-circuit" paths during heating to brazing temperature.

(3) Grain-boundary diffusion resulted in the formation of solid solutions and/or inter-metallic compounds in the grain boundary regions.

(4) "Irrigation," or lateral diffusion of the elements from grain-boundary regions into the base-metal grains, can occur, as evidenced in some tests by the formation and precipitation of compounds of these elements within the base-metal grains.

(5) Incipient volume diffusion, which would occur predominantly at brazing temperature where diffusion would be less structure-sensitive, involved elements of larger atomic radii, as nickel and chromium. Diffusion of these elements into the base-metal surface grains by substitutional diffusion mechanisms resulted in solid-solution formation in this region.

(6) Sometimes the resultant solid solution produced by a diffusion reaction was unstable and decomposed upon cooling from brazing temperature into a solid solution of different composition in an eutectoid matrix.

b. Deviations to the general diffusion reactions occurred in some brazing tests.

(1) The carbon of Brazing Alloy 1 diffused along grain-boundary regions and lattice interstices of the titanium-hardened, iron-base alloy surface grains and reacted with the titanium of this alloy to form titanium carbide. The diffused carbon, by occupying vacancy and dislocation sites in the grain boundaries, and interstices, vacancies and dislocations in the regions of the base-metal grains, actually reduced the free-flow paths available to other elements of the brazing alloy, thereby retarding their diffusion into the base metal.

3. Superheat, or increased brazing temperature above the liquidus of the brazing alloy, generally produced interface structures similar to those obtained at a nominal brazing temperature. The extent of these interface reactions generally increased over the reactions produced at nominal brazing temperatures.

4. Aging at temperatures simulating maximum service temperatures for the particular base alloys produced little change in the microstructural nature of the diffusion reactions, although aging promoted these reactions slightly.

5. Hardness variations across brazed-joint interface regions reflected the nature and extent of the diffusion reaction products that occurred in these regions.

## Appendix I

### *Brazing Alloy 1 Interface Reactions*

When AISI 410 was brazed with Alloy 1, a very restricted solid solution formed at the interface. Some carburization occurred in the base-metal region ahead of the interface. This was produced by interstitial diffusion of carbon into the base metal. The resultant base-metal structure consisted of a hardened martensitic structure (to 644 KHN) which formed upon relatively rapid cooling from brazing temperature. During the superheating test, additional diffusion by substitutional elements of the brazing alloy produced a more pronounced reaction, with a solid solution forming along the interface. The solid solution transformed upon cooling from brazing temperature, to produce a complex (Fe-Cr-Ni-Si) solid solution in an eutectoid matrix of complex solid solution and intermetallic compound (probably borocarbide). Ahead of this diffusion and decomposition reaction, carburization again indicated interstitial diffusion of carbon into the base metal (Figs. 3*a* and 3*b*). After the superheat test, the hardness of the carburized layer was 672 KHN, compared with 336 KHN for the base metal, 769 KHN for the interface decomposition structure and 317 KHN for the resultant brazing-alloy structure (Table 2).

The solid solution produced by incipient volume diffusion reactions of elements in Alloy 1 with elements of AISI 347 was unstable, and transformed, upon cooling, to form a complex solid solution in an eutectoid matrix along the interface region. The eutectoid probably consisted of a complex solid solution (Fe-Cr-Ni-Si) and complex borocarbides. Ahead of this region, some boron, grain-boundary penetration was evident in the base metal. The resultant brazing-alloy structure resembled that of a nickel-chromium-silicon alloy, probably consisting of nickel-chromium-rich solid solution and silicides (Figs. 4*a*, 4*b* and 4*c*). This brazing-alloy structure would be expected only after considerable carbon and boron of the Alloy 1 had migrated into the base metal.

When the titanium-hardened iron-base alloy was brazed with Alloy 1, a "carburization" occurred at the interface region on the surface of the base metal. Apparently the titanium of the base metal reacted, upon heating, with the carbon of the brazing alloy to form titanium carbide (Figs. 5*a*, 5*b* and 5*c*). (The carbon had diffused along the grain boundaries of the base metal as well as interstitially through the lattices of the base-metal surface grains.) Upon formation, this titanium carbide "interface layer" generally retarded grain-boundary diffusion by boron, as well as solution formation by diffusion of silicon, chromium and nickel at the interface. Consequently, the brazing alloy remained high in boron, as well as nickel, chromium and silicon after brazing, as evidenced by the presence of boride and silicide particles in the resultant brazing-alloy structure and the concomitant high hardness of the brazing alloy after brazing (up to 592 KHN). The carbon migration (and TiC formation), by occupying vacancy and dislocation sites in the grain boundaries and lattice interstices, vacancies and dislocation regions in the base-metal grains, restricted further diffusion by reducing the free flow paths[1] available to the migrating atoms of other elements.

When liquid Alloy 1 reacted with the solid titanium-hardened, nickel-base alloy and with the cobalt-base alloy several mechanisms were observed. The carbon and the boron, and perhaps some of the silicon, diffused along the grain boundaries of the base metal during heating and reacted with base-metal elements to form intermetallic compounds in the grain-boundary regions. At brazing temperature, complex solid solutions, involving the nickel, or the cobalt of the particular base materials and the nickel, chromium and silicon of the brazing alloys, were produced by incipient volume diffusion of these elements across the interface and into the base metal, as shown in Figs. 6*a*, 6*c*, 7*a* and 7*c*.

Superheat brazing temperature apparently caused migration of the carbon and or boron in Alloy 1 into the cobalt-base alloy. This carbon and or boron probably reacted with the tungsten of the base metal to form tungsten carbide,

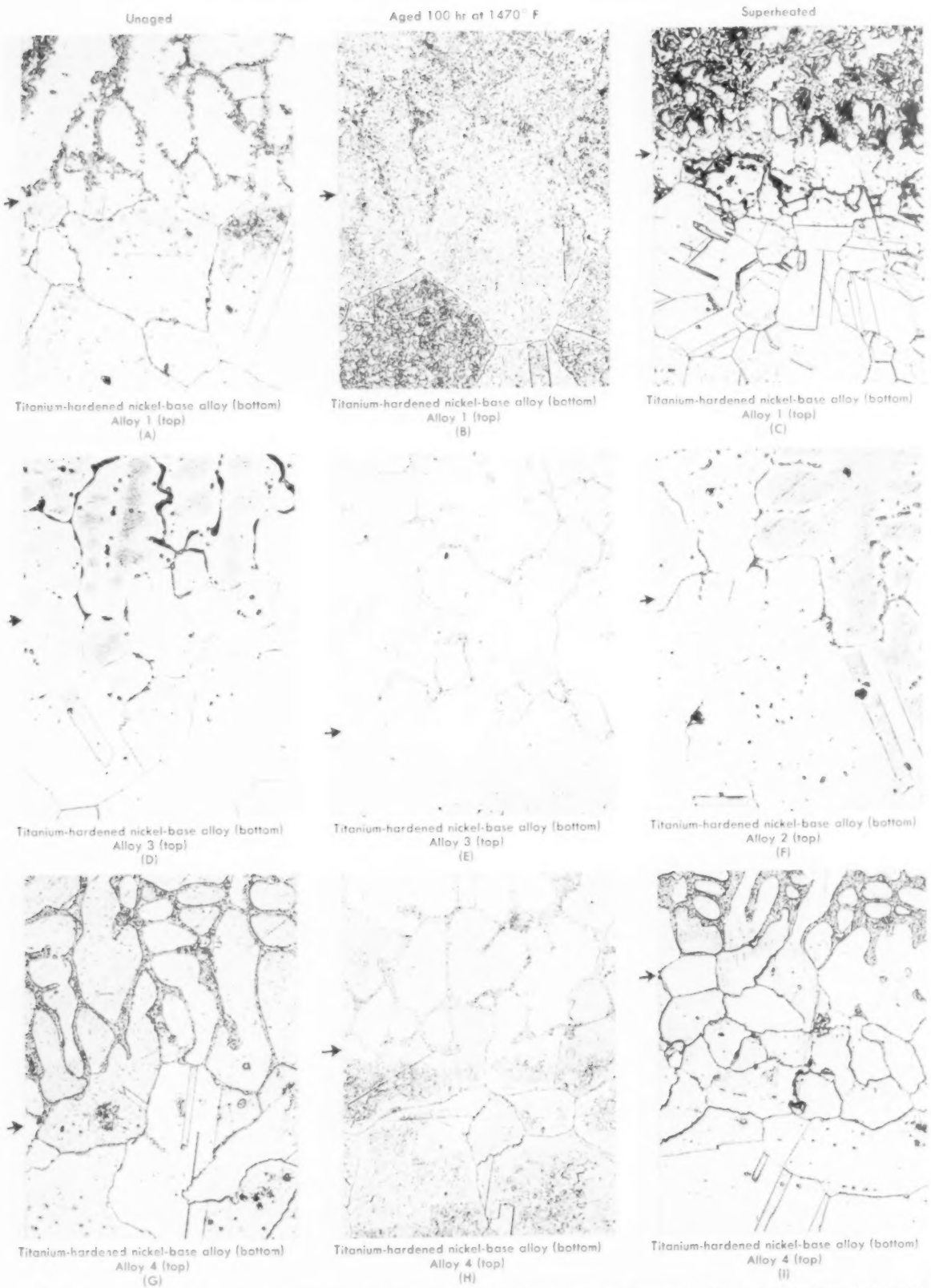


Fig. 6 Unaged and aged microstructures produced by reactions of high-temperature brazing alloys with a titanium-hardened, nickel-base alloy. Arrows indicate the plane of the liquid-solid interface. Fry's etch. X 250

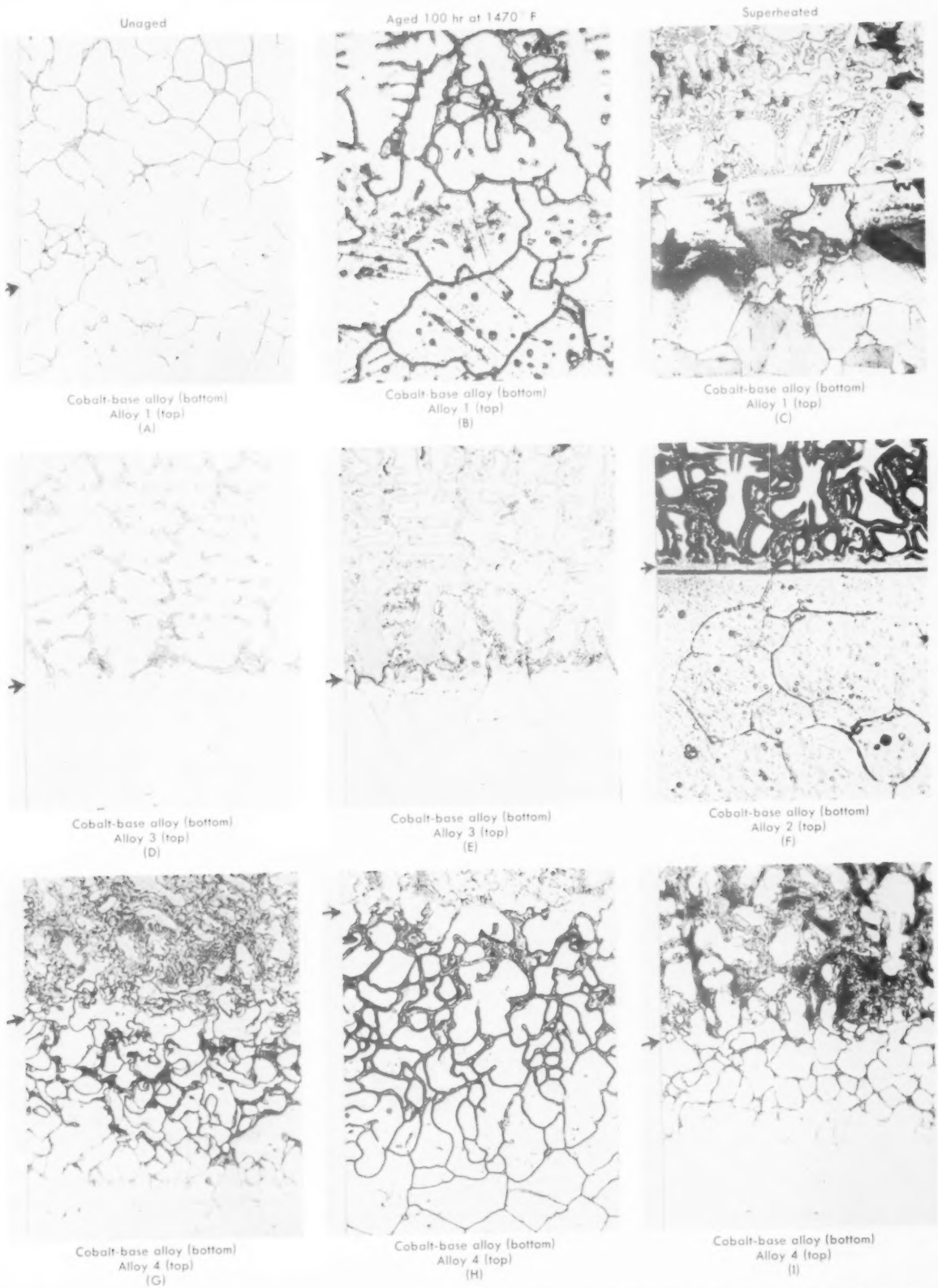


Fig. 7 Unaged and aged microstructure produced by reactions of high-temperature brazing alloys with a cobalt-base alloy. Arrows indicate the plane of the liquid-solid interface. Fry's etch. X 250

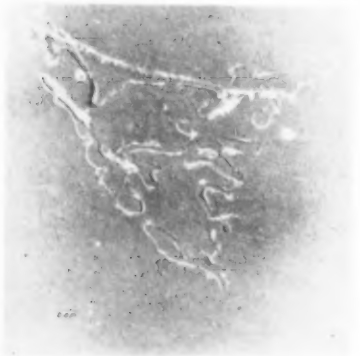

Fig. 8 Diffusion-reaction products at grain boundary triple point in AISI 347 base metal, brazed with a nickel-chromium-silicon brazing alloy. X 7400

Fig. 9 Diffusion-reaction products formed in grain boundaries of AISI 347 base metal, brazed with a nickel-chromium-silicon brazing alloy. X 7400

boride or borocarbide (Fig. 7*c*). Hardness values (423, 382, 395 KHN) in this region tended to confirm the presence of a carbide, boride or borocarbide phase (Table 2). When this reaction had occurred, additional diffusion by other elements of the brazing alloy would be retarded, for the free flow paths would be decreased in the same manner as when the titanium-hardened iron-base alloy became "carburized." The resultant brazing-alloy structure was essentially typical of a Ni-Cr-Si alloy.

#### *Brazing Alloy 2 and Brazing Alloy 3 Interface Reactions*

Brazing AISI 410 with the nickel-chromium-silicon type brazing alloy produced the duplex structure in the base metal shown in Figs. 3*c* and 3*d*. This structure consisted of high hardness, martensitic islands (423, 547 KHN) in an untransformed ferritic matrix (161, 188 KHN). The duplex structure was produced by heating the AISI 410 to a higher brazing temperature range (2150-2210° F) than when Brazing Alloy 1 was used (1970–2060° F). At the higher temperature level, a two-phase region of ferrite-austenite would exist for the iron-chromium alloy. Upon rapidly cooling the AISI 410 material from brazing temperature, the austenitized regions would transform into martensite, to produce the observed, two-phase structure. A spectrographic analysis did not substantiate the possibility that the untransformed ferrite was the result of silicon diffusion into these regions. However, the presence of silicon would stabilize ferrite at brazing temperature.

At the interface, the martensitic structure could be produced by slow, nickel-diffusion into the base metal. In this locality, the base-metal ferrite would contain sufficient austenite-forming nickel, such that austenite would form upon heating to brazing temperature. Upon rapid cooling from brazing temperature, these regions would transform into martensite, as shown in Figs. 3*c* and 3*d*.

Brazing AISI 347 with the nickel-chromium-silicon type brazing alloy produced a grain-boundary reaction throughout the entire $\frac{1}{4}$-in. thick, base-metal specimen. Silicon, possessing a relatively small atomic radius and exhibiting a higher concentration gradient than the other brazing-alloy elements, probably was responsible for this reaction which is evident in Figs. 4*d*, 4*e* and 4*f*. Furthermore, the silicon may have reacted with the niobium or tantalum of the base metal to form an $M_xSi_y$ compound in the grain boundaries. A similar test on AISI 304, which is chemically similar to AISI 347 but does not contain niobium or tantalum, did not produce any grain boundary-reaction product, suggesting that niobium or tantalum was necessary for the reaction. The resultant brazing alloy was preponderantly nickel-chromium-silicon solid solution (relative absence of complex silicides), offering evidence of the diffusion of some of the silicon into the base metal. Spectrographic analyses are under way to establish the nature of this reaction product.

In Figs. 8 and 9, the nature of this reaction product is shown. Here, the grain-boundary structure appears to be an eutectoid network, probably consisting of iron-chromium-nickel-silicon solid solution and $M_xSi_y$ intermetallic compound. The irregular, platelet nature of the compound particles, as well as the low carbon of both the brazing alloy and of the base metal, do not suggest the presence of a carbide phase.

When AISI 347 was brazed with Alloy 2 at superheat brazing temperature, increased diffusion resulted in precipitation within the AISI 347 grains of compounds which appeared to be similar to the grain-boundary compounds produced in the material under "nominal" brazing conditions. Diffusion of silicon, from the grain-boundary regions into the grain lattices, could produce this effect (Fig. 4*f*). Compound formations occurred within the grains as platelets which formed along preferred crystallographic planes. These platelets existed as large "islands" when twin-plane orientations of the grains appeared to be parallel or angled to the path of the diffusing atoms. A row of aligned, thin platelets appeared where twin-plane orientations of the grains seemed to be perpendicular to the path of the diffusing atoms. These platelet compounds could be expected to be weak and susceptible to microcracking. The diffusion reactions produced hardnesses of 157 to 228 KHN in the resultant brazing alloy and 157 to 196 KHN in the resultant base-metal structure.

When the nickel-chromium-silicon brazing alloys reacted with the titanium-hardened iron-base alloy, titanium-hardened nickel-base alloy and cobalt-base alloy, general interdiffusion reactions occurred which resulted in complex solid-solution formations at the interface regions of these base alloys. No base-metal grain-boundary penetration or reaction products were evident in these tests, since very little carbon and no boron were present in the brazing alloys to initiate such a reaction in these alloys. Silicon diffusing into the base metal would tend to form solid solutions with either the nickel or cobalt. Generally, the resultant structures of these brazing alloys were cored, due to non-equilibrium solidification rates from brazing temperature, but otherwise they resembled nickel-chromium-silicon alloy structures.[4]

In the titanium-hardened iron-base alloy—Alloy 2 superheat test, Fig. 5*f*, gross grain-boundary diffusion, probably of silicon, produced a boundary constituent throughout the base-metal structure at the 2210° F brazing temperature. In addition, a coarse precipitate coalesced within the grains of the titanium-hardened iron-base alloy. These precipitated particles in the base metal may be assumed to be high in silicon and perhaps are titanium silicides. A hardness range of 140 to 155 KHN was obtained for this base-metal structure.

#### *Brazing Alloy 4 Interface Reactions*

Nominal and superheat reactions of Brazing Alloy 4 with AISI 410 produced microstructures similar to both those of the nickel-chromium-silicon-boron-carbon and the nickel-chromium-silicon type alloys.

In brazing AISI 410 with Alloy 4 at nominal brazing temperature (2070° F),

Fig. 10 Brazed joint interface microstructure of titanium-hardened, iron-base alloy brazed with a nickel-silicon-boron alloy and aged 100 hr at 1290° F. Compare with Fig. 5*h*. Fry's etch. X 750

an interface structure was produced which was similar to that obtained when the material was brazed with Alloy 1 at superheat temperature (2060° F) (compare Figs. 3*b* and 3*e*). The structure consisted of a solid-solution formation along the interface which decomposed into a complex Fe-Cr-Ni-Si solid solution in an eutectoid matrix of complex solid solution and intermetallic compound (probably boride). In agreement with the Fe-Cr phase diagram,[6] a single austenitic phase existed when AISI 410 was heated to 2070° F and this phase transformed into martensite upon rapid cooling. Heating above this temperature during superheat brazing, to 2150° F, re-transformed some of the austenite into ferrite. When this structure was rapidly cooled from brazing temperature, the austenite transformed into martensite, which formed within a ferrite matrix, as in the sample shown in Fig. 3*f*.

Interface martensite of this test (408 KHN) may again be related to some nickel buildup, through incipient volume diffusion, such that these regions are transformed from austenite upon rapidly cooling from superheat brazing temperature.

When AISI 347, titanium-hardened iron-base alloy and cobalt-base alloy were brazed with Alloy 4, both boron grain-boundary diffusion into the base metal and incipient, volume diffusion reactions were evidenced. In these tests, complex solid solutions were formed at the interface regions, all of which decomposed upon cooling from brazing temperature to form complex solid solutions and complex borides (Fig. 10).

Brazing Alloy 4 reacted with the titanium-hardened nickel-base alloy to form a boron-compound, grain-boundary reaction product (Figs. 6*g*, 6*h*, 6*i*). Migration of boron into the lattices of the base-metal surface grains was also evidenced by the presence of coalesced precipitates in these regions. These precipitates, appearing only in the vicinity of boron grain-boundary diffusion, were probably borides. Elsewhere along the interface, complex solid solutions of Ni-Cr-Si-Fe formed by interdiffusion of these elements. The resultant brazing alloy was essentially nickel-silicon alloy, consisting of nickel-rich solid solution and an eutectoid of nickel-rich solid solution and nickel-silicon intermetallic compound, possibly $Ni_3Si$.*

* $Ni_3Si$ forms upon cooling at 32.5% silicon and about 1815° F.

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# WELDABILITY OF NOTCH-DUCTILE STEELS

*BWRA report indicates that the British carbon equivalent formula may be regarded as a suitable criterion for the limit of weldability of notch-ductile steels*

BY L. REEVE

SYNOPSIS. Weldability tests are described which have been carried out on a series of carbon-manganese steels, including a number of ND (notch ductile) steels supplied in accordance with the new British Standard Specification 2762 (1956) for notch-ductile steels. CTS and Battelle cracking tests have been used. It has been shown that the results obtained are more in accordance with the British carbon equivalent formula than with the Battelle formula for weldability.

## Introduction

During the past few years, British steelmakers have developed a series of steels of improved notch ductility as compared with ordinary mild-steel structural grades, known as the *ND* (notch ductile) series. This development has arisen from a growing realization of the importance of improving the resistance of mild steels to brittle fracture, particularly when used in welded structures. While there is at present no full agreement as to the most suitable criterion of such resistance, it is generally accepted that some notched type of test piece should be employed, preferably at sub-atmospheric temperatures.

These new British steels which have recently been covered by British Standard Specification 2762 (1956) are based upon a guaranteed Charpy V-notch impact value of not less than 20 ft-lb at steadily falling temperatures, as indicated in Table 1, which is summarized from B.S. 2762. It will be noted that from *ND I* to *ND IV* the temperature for 20 ft-lb Charpy steadily drops from 0 to 50° C. The foreword to the B.S. specification points out that "the fact that low temperatures are used for these tests does not necessarily imply that the steels are guaranteed as being completely satisfactory for use at these temperatures, though in general they can be regarded as progressive improvements over ordinary mild steel in the order shown in the Table."

The improvement in Charpy values possessed by these steels, in comparison with ordinary mild steel to B.S. 15, is illustrated in Fig. 1, which shows average values at a range of temperatures down to −50° C for a considerable number of 1-in. thick plates of these *ND* steels, compared with ordinary mild steel. It will be noted that the value attained for each of the *ND* steels at the temperatures specified in Table 1 has in actual fact been considerably exceeded, but it should be noted that the specification covers plates up to 2 in. in thickness, whereas the results given in Fig. 1 are for 1-in. plates only. (Thinner plates, other things being equal, tend to give better impact results.)

The chemical specification for these *ND* steels is shown in Table 2, also reproduced from B.S. 2762, while some representative analyses, mainly of *ND I* steels, will be found in Table 3A. (The steels marked with an asterisk should be excluded, as they have been deliberately made outside normal specifications for reasons described later. Steel 4, with a carbon content of 0.175%, is also reported by the maker to be slightly above his normal composition with respect to this element.) All the *ND* steels are of the low carbon-high manganese type, *ND I* and *ND II* being of the so-called semikilled or balanced (low silicon) type, while *ND III* and *ND IV* are silicon killed steels. The latter steel is the only one of the four which is specified to be "fine grained," though *ND III* may, in certain cases, be of the same type. Fine graining involves treating the steel with small quantities of aluminum.

Report FM 8/131 of the British Welding Research Association issued to members in November 1956.

This report was presented to the FMS Committee on "Welding Low Alloy Steels" by L. Reeve on behalf of the Heavy Steel Association's Technical Committee.

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Table 1—Tensile and Impact Properties of *ND* Steels

| *Grade* | *Tensile strength, tons/in.²* | *Elongation — Test piece A, %* | *Elongation — Test piece C, %* | *Impact properties (Charpy V-notch) — Temp, °C* | *Minimum average of 3 tests, ft-lb* | *Minimum individual test, ft-lb* |
|---|---|---|---|---|---|---|
| *ND I* | 26-31 or 28-33 | 20 | 25 | 0 | 20 | 15 |
| *ND II* | 26-31 or 28-33 | 20 | 25 | −15 | 20 | 15 |
| *ND III* | 26-31 or 28-33 | 20 | 25 | −30 | 20 | 15 |
| *ND IV plates* | 26-31 or 28-33 | 20 | 25 | −10 | | 45 |
| | | | | −20 | | 40 |
| | | | | −30 | | 35 |
| | | | | −40 | | 25 |
| | | | | −50 | | 20 |
| *ND IV sections* | 26-31 or 28-33 | 20 | 25 | −10 | 45 | 35 |
| | | | | −20 | 40 | 30 |
| | | | | −30 | 35 | 25 |
| | | | | −40 | 25 | 20 |
| | | | | −50 | 20 | 15 |

in a carefully controlled manner, in addition to silicon killing, and also usually involves normalizing the steel. It will be noted from Table 2 that the specified maximum carbon content for *ND I* and *ND II* is 0.20%, while for *ND III* and *ND IV* it is 0.17%. In fact most steelmakers work to a maximum of 0.17% for all four steels, as may be seen from Table 3(*a*). The only exception in this Table is Plate 9, which had a carbon content of 0.18%, but it also had a relatively low manganese content of 0.90%, and its tensile strength of 30.5 tons in.$^{-2}$ is well below the maximum allowed. (The steels marked with an asterisk also have carbon contents exceeding 0.17%, but these, as already indicated, have been deliberately made outside normal *ND* specification, as may be seen from their tensile strengths.)

Increasing quantities of steel similar to *ND I* have been used during the past five years for shipbuilding, though it has been supplied to a different type of specification, and small, though increasing, quantities of *ND IV* have also been used. Lloyds *XVT* steel, for example, is substantially identical with *ND IV*.

Increasing quantities of these steels are also being called for by the oil industry for oil storage tanks and similar equipment, and in actual fact it was the requirements of this industry which led to the drawing up of these specifications in the first place. B.S. Specification No. 2762 (1956) was based upon these original specifications, though like all B.S. specifications, its final form was agreed by representatives of various industries and large users in consultation with the steelmakers. Large quantities of these steels have been successfully site welded in both the oil industry and in shipbuilding.

### Weldability of *ND* Steels

During the later stages of discussion between the steelmakers (represented by the Heavy Steels Associations Technical Committee), and the oil industry (represented by Oil Companies Materials Committee), attention was drawn to the question of the weldability of these *ND* steels. It was pointed out that current American ideas on weldability were based upon the results of the so-called "Battelle Underbead" test, which is described by Stout and Doty in their book, "Weldability of Steels."* A detailed account of the method of carrying out this test is given in Appendix I. The important point which should be mentioned right away is that the Battelle investigators concluded from their results that for

* Stout, R. D., and Doty, W. d'Orville, "Weldability of Steels," Welding Research Council, 225-229, New York 1953.

Table 2—Chemical Composition of *ND* Steels

| | *Grades ND I and II*, % | | *Grades ND III and IV*, % | |
|---|---|---|---|---|
| *Element* | *min* | *max* | *min* | *max* |
| Carbon | | 0.20 | | 0.17 |
| Silicon | | | 0.10 | 0.35 |
| Manganese | | 1.50 | | 1.50 |
| Sulphur | | 0.060 | | 0.050 |
| Phosphorus | | 0.050 | | 0.050 |

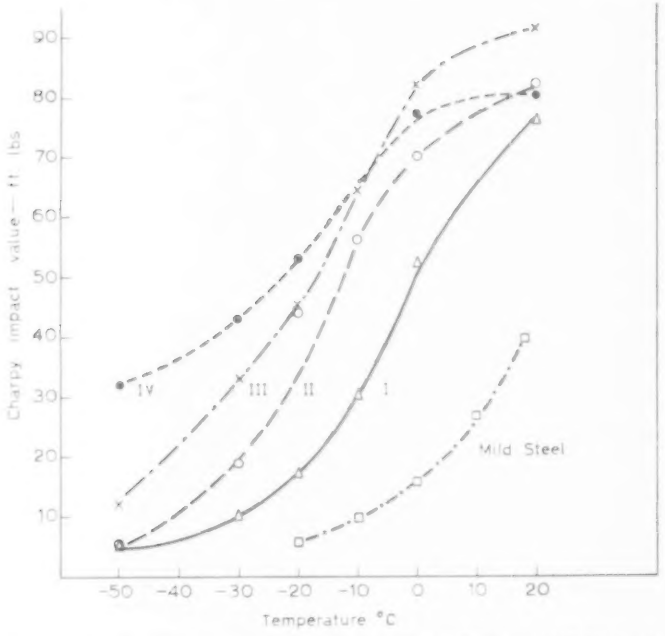


Fig. 1 Typical transition curves for *ND I*, *ND II*, *ND III*, and *ND IV* steels approximately 1 in. thick (Charpy V-notch)

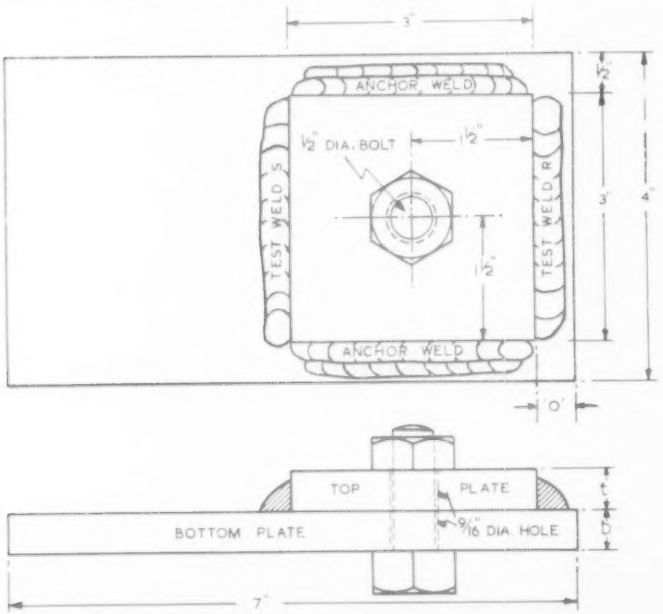


Fig. 2 The *CTS* test piece

carbon–manganese steels, freedom from underbead cracking could be ensured only if the analysis of the steel met the following requirement:

$$\%C + \frac{\%Mn}{4} + \frac{\%Si}{4}$$ must not exceed 0.40†

(See Stout and Doty's book, p. 150, Fig. 5.13, and also papers by Williams, Roach, Martin and Voldrich.[1])

It will be noted that on the basis of this criterion all the *ND* steels shown in Table 3A would be considered as unsatisfactory. In fact, many ordinary mild steels would be put in the same unsatisfactory class, particularly if they included some silicon in addition to manganese in their chemical composition. At least, this would be the case if the criterion of complete freedom from cracking in the underbead test is regarded as the criterion of weldability, though this is not clearly stated in Stout and Doty's book. In an earlier paper by Voldrich[2] weldability was regarded as satisfactory for practical purposes if the length of crack in the Battelle test did not exceed 40%. This, however, is not repeated in the later publications.

British conclusions as regards weldability of carbon-manganese steels have been based upon the use of the Reeve cracking test and were summarized as far back as 1940 by Dearden and O'Neill,[3] and by the old R 11 (now FM 8) Committee of the British Welding Research Association,[4] in their carbon-equivalent formula which, in effect, stated that steels would be free from hardened zone cracking in the Reeve test if

$$\%C + \frac{\%Mn}{6} + \frac{\%Cr}{5} + \frac{\%Mo}{4}$$ did not exceed approx. 0.45

† Editor's Note: In a statement released in September 1957, Dr. R. D. Stout pointed out that carbon equivalent calculation serves as a rough guide and is by no means a "specification."

**Table 3A—Weldability Tests on *ND* Steels, Chemical Analysis**

| *Plate no.* | *Cast no.* | *Thickness, in.* | *Plate analysis, %* | | | | | *Hardenability index* | |
|---|---|---|---|---|---|---|---|---|---|
| | | | *C* | *Mn* | *P* | *S* | *Si* | $C + \frac{Mn + Si}{4}$ | $C + \frac{Mn}{6}$ |
| 1 | 69734 | 1 26 | 0 160 | 1 44 | 0 028 | 0 028 | 0 141 | 0 56 | 0 40 |
| 2 | 69733 | 1 05 | 0 160 | 1 17 | 0 023 | 0 029 | 0 045 | 0 47 | 0 36 |
| 3* | 4742 | 0 95 | 0 230 | 1 55 | 0 046 | 0 051 | 0 122 | 0 65 | 0 49 |
| 4 | 609 | 1 25 | 0 175 | 1 34 | 0 034 | 0 047 | 0 195 | 0 56 | 0 40 |
| 5 | 8156 | 1 00 | 0 130 | 1 05 | 0 026 | 0 022 | 0 040 | 0 40 | 0 31 |
| | 2 2 | | | | | | | | |
| 6 | W3784 | 1 00 | 0 135 | 1 24 | 0 017 | 0 019 | 0 050 | 0 46 | 0 34 |
| 7 | H3436 | 1 00 | 0 195 | 1 24 | 0 020 | 0 037 | 0 060 | 0 52 | 0 40 |
| * | 1 2 | | | | | | | | |
| 8 | 16168 | 1 12 | 0 155 | 0 87 | 0 029 | 0 040 | 0 040 | 0 38 | 0 30 |
| 9 | 2205H | 1 18 | 0 180 | 0 90 | 0 027 | 0 042 | 0 050 | 0 42 | 0 33 |
| 10* | 2745 | 1 03 | 0 220 | 1 62 | | | | 0 64 | 0 39 |
| 11 | 4670 | 1 25 | 0 150 | 1 09 | 0 036 | 0 044 | 0 210 | 0 48 | 0 33 |

* These plates not *ND 1* quality, but used for checking Battelle test.

**Table 3B—Weldability Tests on *ND* Steels, Mechanical Properties**

| *Plate no.* | *Direction of test* | *Tensile properties* | | | | *Impact properties* | | *Transverse bend test* ($D = 3T$) | *Maker* |
|---|---|---|---|---|---|---|---|---|---|
| | | *Y.P., tons/in.²* | *M.S., tons/in.²* | *Elongation, % on 3 in.* | *Reduction in area, %* | *Charpy V-notch, ft-lb — At room temperature* | *At 0° C* | | |
| 1 | L | 19 50 | 31 00 | 21 0 | 37 0 | (+21°C) 67 67 73 Av. 69 | 61 56 51 Av. 56 | Satisfactory | A |
| 2 | L | 17 30 | 30 80 | 27 0 | 55 6 | (+21°C) 85 77 88 Av. 83 | 59 56 54 Av. 56 | Satisfactory | A |
| 3† | L | | 40 30 | 19 6 | | | | | A |
| 4 | L | 19 70 | 33 20 | 23 0 | 53 5 | | 32 35 27 Av. 31 | | B |
| | X | 19 65 | 32 90 | 24 5 | 45 6 | | | Satisfactory | C |
| 5* | L | 15 50 | 27 20 | 35 0 | 48 0 | (+20°C) Av. 83 | Av. 65 | | |
| | X | | | | | (+20°C) Av. 50 | Av. 30 | | |
| 6* | L | 20 50 | 28 10 | 33 0 | 63 0 | (+20°C) Av. 80 | Av. 50 | | C |
| | X | | | | | (+20°C) Av. 35 | Av. 23 | | |
| 7†* | L | 18 30 | 34 20 | 32 0 | 54 0 | (+20°C) Av. 65 | Av. 25 | | C |
| | X | | | | | (+20°C) Av. 43 | Av. 26 | | |
| 8 | L | | | | | (+20°C) 53 58 51 Av. 54 | 21 20 18 Av. 20 | | D |
| | X | 14 60 | 28 30 | 30 0 | 55 7 | | | Satisfactory | |
| 9 | L | | | | | (+20°C) 69 49 77 Av. 62 | 39 33 38 Av. 37 | | D |
| | X | 15 30 | 30 30 | 24 0 | 46 3 | | | Satisfactory | |
| 10† | L | 20 10 | 35 00 | 18 0 | 37 9 | 70 59 58 Av. 62 | 30 36 Av. 33 | | D |
| 11‡ | L | 19 25 | 30 70 | 30 0 | 62 5 | | 74 78 74 Av. 75 | Satisfactory | B |
| | X | 19 30 | 30 90 | 25 5 | 52 8 | | | | |

* Tensile tests on 0.564-in. diam. round specimens with 2-in. gage length.
† These plates not *ND 1* quality, but used for checking Battelle test.
‡ Normalized 910° C.

Table 4—Weldability Tests on *ND* Steels. Details of Cracking Tests

| | Battelle underbead cracking test | | | | Controlled thermal severity test | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Severity no. 8 | | | | | | Severity No. 12 | | | | | |
| | | | | | Av. hardness, HD 10 | | | Cracking, % | | | Av. Hardness, HD 10 | | | Cracking, % | | |
| Plate no. | Electrode and size | Welding conditions | Crack, % | Electrode and size | Welding conditions | Vert. leg | Horiz. leg | Weld metal | Plate | Heat-affected zone | Weld | Vert. leg | Horiz. leg | Weld metal | Plate | Heat-affected zone | Weld |
| 1 | X 10 g | 100 amp; 8/14 ipm | Nil | X 10 g | 118 amp; 14 ipm | 365 | 360 | 263 | 175 | Nil | Nil | 383 | 395 | 292 | 175 | Nil | Nil |
| | | | | Y 8 g | 155 amp; 10 ipm | 294 | 283 | 208 | 161 | Nil | Nil | 326 | 327 | 209 | 166 | Nil | Nil |
| | | | | Y 6 g | 200 amp; 8 ipm | 282 | 247 | 208 | 155 | Nil | Nil | 300 | 259 | 209 | 160 | Nil | Nil |
| 2 | X 10 g | 100 amp; 8/14 ipm | Nil | Y 8 g | 155 amp; 10 ipm | 293 | 272 | 192 | 156 | Nil | Nil | 301 | 314 | 193 | 161 | Nil | Nil |
| | | | | Y 6 g | 200 amp; 8 ipm | 285 | 274 | 195 | 187 | Nil | Nil | 317 | 303 | 226 | 165 | Nil | Nil |
| 3* | X 10 g | 100 amp; 8/14 ipm | 8/27 6% | | | | | | | | | | | | | | |
| 4 | X 10 g | ac; 15,000 J/in. | Nil | X 10 g | ac | 399 | 373 | 316 | 173 | 1/3, 0/4, 1/2 | Slight crack in 1/3 | 390 | 386 | 251 | 171 | 1/4, 1/6, 5/5, 4/4 | Nil |
| | X 10 g | dc; 15,000 J/in. | Nil | X 10 g | dc | 392 | 403 | 236 | 180 | 0/6, 0/4, 1/3 | Nil | 394 | 391 | 236 | 171 | 0/3, 1/3, 4/3 | Nil |
| | X 10 g | dc; 15,000 J/in. | Nil | Y 8 g | ac | 316 | 368 | 220 | 174 | Nil | Nil | 388 | 386 | 247 | 172 | Nil | Nil |
| 4R | X 10 g | ..... | Nil | Y 6 g | ac | 366 | 336 | 205 | 177 | Nil | Nil | 354 | 354 | 205 | 172 | Nil | Nil |
| 5 | X 10 g | dc | Nil | X 10 g | dc; 20,100 J/in. | 302 | | 265 | 148 | Nil | Nil | 330 | | 288 | 147 | Nil | Nil |
| | Y 10 g | dc | Nil | Y 8 g | dc; 32,500 J/in. | 260 | | 236 | 154 | Nil | Nil | 254 | | 232 | 164 | Nil | Nil |
| | | | | Y 6 g | dc; 56,500 J/in. | 238 | | 224 | 167 | Nil | 10% in 1/6 | 263 | | 218 | 156 | Nil | Nil |
| 6 | X 10 g | dc | Nil | X 10 g | dc; 20,100 J/in. | 315 | | 284 | 149 | Nil | Nil | 313 | | 350 | 158 | Nil | 100% in 1/3 |
| | Y 10 g | dc | Nil | Y 8 g | dc; 32,500 J/in. | 224 | | 175 | 154 | Nil | 5% in 1/6 | 289 | | 200 | 149 | Nil | Nil |
| | | | | Y 6 g | dc; 56,500 J/in. | 223 | | 201 | 159 | Nil | Nil | 231 | | 225 | 154 | Nil | 20% in 3/6 |
| 7* | X 10 g | dc | Nil | X 10 g | dc; 20,100 J/in. | 419 | | 221 | 190 | 8% in vert. leg of 1/6 | Nil | 347 | | 280 | 192 | 10% + 4% in horiz. leg of 2/6 | 100% in 2/6; 10% in 1/6 |
| | Y 10 g | dc | Nil | Y 8 g | dc; 32,500 J/in. | 357 | | 264 | 200 | 6% H & 9.7% VH in 2/6 | Nil | 368 | | 246 | 190 | 4.3% in horiz. leg of 1/6 | Nil |
| 7R | X 10 g | ..... | 7% | Y 6 g | dc; 56,500 J/in. | 327 | | 186 | 180 | 2.5% in 2/6 | 10% in 1/6 | 375 | | 220 | 179 | 0.5% in vert. leg of 1/5 | Nil |
| 8 | X 10 g | 100 amp; 10 ipm | Nil | X 10 g | 110 amp | 267 | 282 | 270 | 139 | Nil | Nil | 276 | 267 | 257 | 137 | Nil | Nil |
| | | | | Y 8 g | 155 amp | 276 | 288 | 212 | 131 | Nil | Nil | 272 | 287 | 211 | 136 | Nil | Nil |
| | | | | Y 6 g | 200 amp | 258 | 246 | 193 | 135 | Nil | Nil | 264 | 265 | 191 | 134 | Nil | Nil |
| 9 | X 10 g | 100 amp; 10 ipm | Nil | X 10 g | 110 amp | 216 | 210 | 241 | 135 | Nil | Nil | 235 | 225 | 228 | 141 | Nil | Nil |
| | | | | Y 8 g | 155 amp | 248 | 233 | 213 | 139 | Nil | Nil | 263 | 243 | 209 | 141 | Nil | Nil |
| | | | | Y 6 g | 200 amp | 210 | 192 | 182 | 140 | Nil | Nil | 214 | 211 | 188 | 144 | Nil | Nil |
| 10* | X 10 g | 100 amp; 10 ipm | 10-25% | | | | | | | | | | | | | | |
| 11 | X 10 g | ..... | 1% | | | | | | | | | | | | | | |

* Not *ND I* quality: used to check Battelle tests only.

silicon in quantities up to at least 0.5% was found to have little effect on hardness of heat-affected zone and does not enter into the formula. The formula applied to plates ½ in. thick using 8-g electrodes or 1 in. thick using 4-g electrodes. Similar conclusions would be expected from the miniature Reeve test and its B.W.R.A. modification known as the *CTS* test,[3] though no systematic investigation on this point has been carried out.

On the basis of the British carbon-equivalent formula, all the steels in Table 3 (excluding Plates 3 and 10) should have satisfactory weldability.

In view of the apparent contradiction between the conclusions from the Battelle and the Reeve (or *CTS*) tests as applied to the *ND* steels, it was felt highly desirable to test a series of these steels by both methods, and to compare results. Arrangements were therefore made by five major British plate manufacturers to supply a range of their normal *ND I* steels of varying composition, together with a few steels outside the range, all in the form of plates approximately 1 in. thick, for carrying out these tests. Most of the testing was carried out by the steelworks themselves, but three plates were also supplied to the oil companies who arranged for check Battelle tests to be carried out on them by their associated laboratories. Details of all the steels supplied, together with mechanical and impact test properties, are given in Tables 3A and B. The agreed procedure for carrying out the Battelle underbead test is given in Appendix I, this being an abstract from Stout and Doty's book, pp. 225 and 226. The temperature of the water in which the pieces were immersed was agreed to be 15–20° C at the commencement of the test.

The details of the modified *CTS* test are given in Appendix II, and have been abstracted from the B.W.R.A journal, *Welding Research*.[3] The test as described in the journal uses 8-g electrodes only. It was decided, however, to extend the test by the use of 10-and 6-g electrodes in addition to 8 g. Further, the official *CTS* test covers a range of plate thicknesses which allows the thermal severity to be changed between wide limits. This full series of tests did not appear to be necessary and it was agreed to start the tests on 1-in. plate only at thermal severities of 8 and 12, corresponding to welds R and S of Fig. 2 in Appendix II. If either of these welds showed appreciable hardened-zone cracking, it was agreed to repeat the tests at a reduced thermal severity of 6 and 10 by reducing the top-plate thickness to ½ in. as shown in Table 5 of Appendix II. In the event, this turned out to be unnecessary as the degree of cracking of the 1-in. *ND* steels in the *CTS* test was found to be negligible. Two makes of electrodes, X and Y, were used in the tests. In the Battelle underbead tests these are both in 10-g size, as called for by the test. X was a cellulosic-high hydrogen type, E.110.P, while Y was a rutile type, E.317.

The same 10-g electrode, type X, was used in the modified CTS tests, together with 8-g and 6-g sizes of electrode type Y.

## Results of Weldability Tests

A summary of the test results obtained is given in Table 4. Test 4R and 7R are repeat Battelle tests carried out by the oil companies' laboratories, while 11 was also carried out by them. All the remaining tests were carried out by the steel companies.

It will be noted that all the true *ND* steels (all the steels apart from steels 3, 7 and 10) gave substantial freedom from cracking in the Battelle tests, although most of them do not meet the Battelle carbon - equivalent formula. This is also substantially true for the modified *CTS* tests, severities 8 and 12, where slight cracking in the weld metal only was reported for Plates 6 and 5, with very slight heat-affected zone cracks at the root of the weld in Plate 4, (10-g electrodes only.) Such small electrodes are not normally used on 1-in. plate.

Plate 7, with a carbon content of 0.19% and a tensile strength of 34 tons/in.², is outside the *ND* specification, and has given some cracking (7%) in the repeat Battelle test 7R, together with a little heat-affected zone cracking in the *CTS* tests with all electrodes. The extent is marginal, being less than 10% of the leg length in only one or two of the six sections examined. There was also some cracking in the weld metal of one test on this steel.

The carbon equivalent by the British formula on this steel is 0.40, and on this basis it should therefore have been free from cracks—at least with the largest electrodes. On the other hand, Steel 1, with the same carbon equivalent of 0.40, was completely free from cracking, and Steel 4, again with the same carbon equivalent, was also completely free except for very slight cracks when using 10-g electrodes only.

## Addendum on the Influence of Aluminum Additions

A further factor influencing weld-

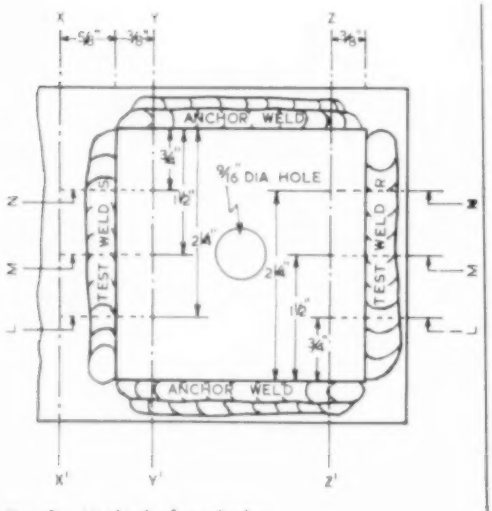


Fig. 3 Method of sectioning

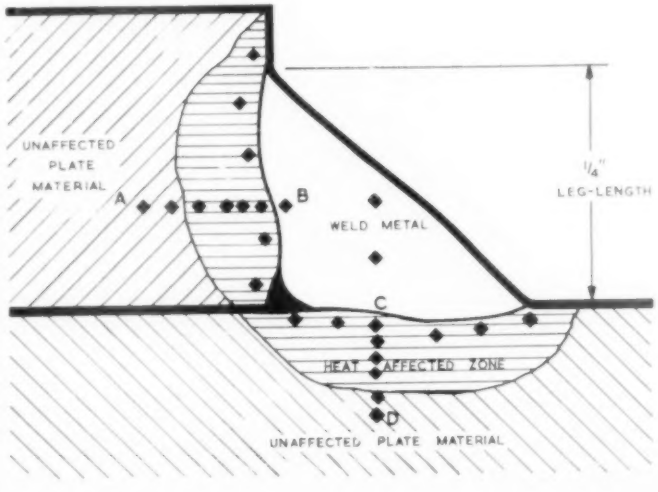


Fig. 4 Hardness survey

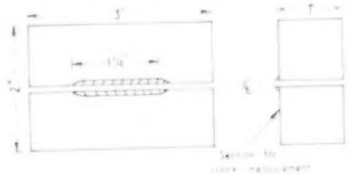

Fig. 5 Longitudinal bead-weld cracking specimen from 1-in. thick plate

ability as measured by the Battelle test was stated to be residual aluminum content of the steel; see Stout and Doty's book, p. 150, which refers to a paper by Sims and Banta.[5] Figure 11 of this paper suggests that very low or very large Al additions are satisfactory, but intermediate values have a marked effect in increasing underbead cracking, the most marked effect being shown between about 0.005 and about 0.03% acid soluble aluminum. Sims and Banta go on to say, however, that "from other evidence it appears that this effect depends on other factors as well." They give no further details.

In view of this possible factor, aluminum figures were determined by the steelmakers for a number of the steels reported in Table 3A, the available figures being as follows:

| *Plate no.* | *Al content* |
|---|---|
| 1 | 0.004% |
| 2 | 0.002% |
| 4 | Nil |
| 7 | Nil |
| 8 | 0.004% |
| 9 | 0.004% |
| 11 | 0.013% |

Making allowances for the difficulties of estimating these low percentages of aluminum, there does not appear to be any association between them and the extent of cracking. Thus, Plates 4 and 7, which showed very slight cracking, had no aluminum at all, whereas Plate 1, which was completely free from cracking, had an Al content somewhere near the peak figure mentioned by Sims and Banta.

Similarly, Plate 11, which had the highest Al content in the series (0.013%) at the peak cracking value, had only 1% cracking in the Battelle test.

The *ND IV* fine-grain steels normally carry about 0.02 to 0.04% aluminum, but there is no evidence that they give any particular cracking troubles in practice. Further investigation of this point by an impartial investigator would appear to be desirable, since the use of these steels is likely to extend, and the authority of the American Welding Research Council has been quoted as supporting the Sims and Banta conclusions regarding the deleterious influence of aluminum.

## Conclusions

(1) A carbon equivalent of 0.40 by the British formula $\%C + \frac{\%Mn}{6}$ may be regarded as a suitable criterion for the limit of weldability of these steels, whether this is determined by the *CTS* test or the Battelle test, the latter, if anything, being slightly less severe than the former.

(2) The Battelle carbon-equivalent formula, $\%C + \frac{\%Mn + \%Si}{4}$ on the other hand appears to overrate grossly the susceptibility to failure of these carbon-manganese steels.

(3) Finally, the *ND* steels as normally supplied by British steelmakers are regarded as fully weldable when using electrode sizes appropriate to their thickness.

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## APPENDIX I: The Longitudinal-Bead-Weld Underbead-cracking Test

On the basis of a test originated by Luther, Laxar and Jackson[7] several investigators at Battelle Memorial Institute have developed a test for determining the underbead-crack sensitivity of steel; small blocks, 2 in. wide by 3 in. long in the direction of rolling and the full thickness of the plate, are cut from the material in the condition in which it is to be welded, and a weld bead, 1¼ in. in length, is deposited on the surface of each block, as shown in Fig. 5. The bead is deposited with a ⅛-in. diam E6010-type electrode, a current of 100 amp at 24–26 v, and a travel speed of 10 in. /min (energy input of 15,000 J/in.); the small blocks are precooled or preheated to one of several temperatures,* such as 0° F (−18° C), 70° F (21° C), or 212° F (100° C), and during welding and for one minute afterwards are immersed to within ¼ in. of their top surface in a liquid bath at the chosen temperature. After removal from the bath, the specimens are held for 24 hr at 60° F (15° C) and then tempered at 1100° F (595° C) for 1 hr. Since, almost without exception, underbead cracks intersect the vertical centerline of the weld bead, they may best be exposed for examination by a longitudinal section, such as shown in Fig. 6. From this section, the presence of underbead cracks may be detected by either a magnetic particle or a metallographic technique. In both cases, the total length of the cracks in any one specimen is determined and expressed

* Early work at Battelle was done mainly at 0° F. Recent tests have been chiefly at 70° F. The tests on the *ND* steels were all carried out at 59–68° F (15–20° C), which was also the temperature of the water bath.

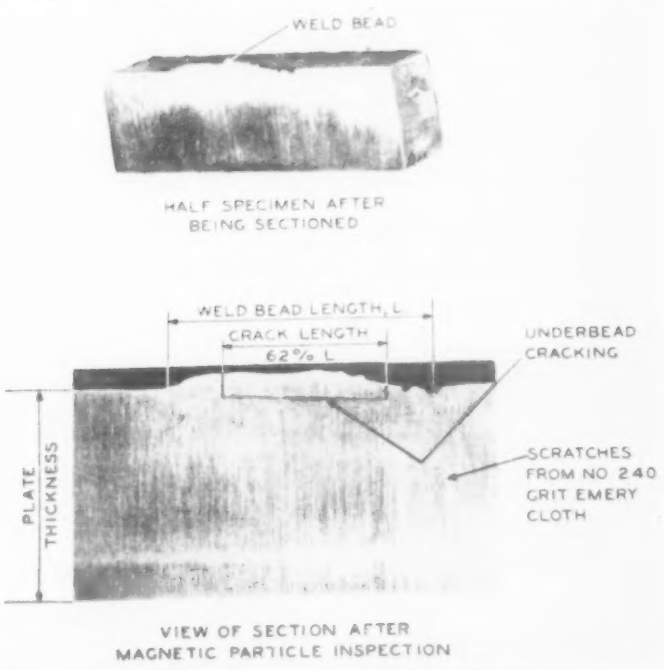


Fig. 6 Typical longitudinal bead-weld cracking specimen from 1-in. thick plate

as a percentage of the bead length. When adjacent cracks overlap, the length of overlap is not counted. Although the extent of cracking has been found to vary considerably from specimen to specimen, the average of ten tests has been found to be reproducible within about 10%. The average of five tests is reproducible within about 20%.

## APPENDIX II: Modified *CTS* Weldability Test as Applied to Notch-Ductile Steels

For reference, details of the full CTS Weldability Test appear in *Welding Research*, October, 1952.[8] For the purpose of assessing the weldability of *ND H* steels a slightly modified CTS test equivalent to thermal severity numbers of 8 and 12 is suggested. If this assembly appears too severe, further tests could be carried out with an assembly giving thermal severity numbers of 6 and 10.

Details of the suggested test are given below:

### Preparation of Test Pieces

Test pieces should be machined from as-rolled plate in accordance with the details given in Fig. 2. If gas cutting is used to cut to rough size, the edges of the top plate must be machined or ground. The under surface of the top plate and the upper surface of the bottom plate must be machined or surface-ground in all cases to remove mill scale.

Details of the plate thickness with the appropriate Thermal Severity Numbers (T.S.N.) are given in Table 5.

### Test Procedure

The top plate should be bolted to the bottom plate taking care that no grease, oil or dirt is trapped between the two.

*Anchor Welds*—Anchor welds should be laid using the test electrode; guidance being given as to the appropriate size of anchor fillet in Table 7. Multiple-run anchor welds, deposited in quick succession, can be used.

Table 7—Size of Anchor Fillet

| *Thickness of top plate, in.* | *Average leg length, in.* |
|---|---|
| ½ | 0.30 |
| 1 | 0.40 |

After depositing anchor welds the assembly is allowed to cool to room temperature and any slackness in the bolt taken up before the test weld is made.

*Test Welds*—The electrodes to be used for the test welds should be dried for 1 hr at 110° C immediately before use. To ensure true downhand welding, it is customary to tilt the test assembly at an angle of 45 deg to the horizontal. This can be conveniently carried out by gripping the assembly in a vise with small pieces of heat-insulating material between vise and assembly, thus ensuring no metallic contact. Test weld R should be laid down first, and the whole assembly allowed to cool to room temperature before test weld S is made. These tests are to be carried out on three separate test assemblies using 10-g electrode X, 8- and 6-g electrode Y, respectively. The test program will be tabulated on a separate sheet.

Table 5—Plate Thickness and Thermal Severity Numbers

| *Test assembly* | *Test weld* | *T.S.N.* | *Remarks* |
|---|---|---|---|
| Top plate (*t*) th. = 1 in. | *R* | 8 | 1st series of tests |
| Bot. Plate (*b*) th. = 1 in. | *S* | 12 | |
| Top Plate (*t*) th. = ½ in. | *R* | 6 | 2nd series of tests if 1st series is too severe |
| Bot. Plate (*b*) th. = 1 in. | *S* | 10 | |

The dimension shown as 'O' in Fig. 2 depends on the size of test fillet. For guidance, Table 6 has been drawn up giving proposed dimensions with given gages of electrodes.

Table 6—Proposed Dimensions of Test Fillet

| *Electrode gage* | *Fillet size suggested leg length, in.* | *Dimension 'O'* |
|---|---|---|
| 10 g | 0.20 | 0.250 (¼ in.) |
| 8 g | 0.25 | 0.3125 (5/16 in.) |
| 6 g | 0.30 | 0.375 (⅜ in.) |

### Examination

The assembly is left at room temperature for at least 24 hr before sectioning. Figure 3 shows the method of sectioning, cuts along $XX^1$, $YY^1$ and $ZZ^1$ being made with a mechanical saw or milling cutter. The individual microsections should be cut out with a hand hacksaw. The sections are polished on faces L, M and N shown in Fig. 3 and examined for hard-zone and weld cracking after etching in 1% Nital. The length of any hard-zone cracks should be measured (see Assessment of Weldability). A magnification ×200 is considered suitable.

*Hardness Survey*—A hardness survey can be carried out on the middle microsection from each test weld in accordance with the diagram shown in Fig. 4. A load of 10 kg with a diamond indentor is used.

To determine the zone of maximum hardness in the heat-affected zone, a few indentations are first made on a line across the fusion line (AB and CD, in Fig. 4). Subsequent indentations are made in the plane of maximum hardness parallel to the fusion line. A spacing of 1 mm between impressions is suggested as being suitable for the final survey. The hardness of base plate and weld metal should also be recorded.

### Assessment of Weldability

In the official *CTS* test the assessment of weldability is determined solely by the thermal severity of the test assemblies which have cracked using 8-g electrodes only, e.g., if no cracking occurs even at a thermal severity of 12, the steel is given a weldability Index A. It is suggested that in this series the weldability should be assessed by the percentage cracking at each degree of thermal severity. The total length of cracking in the vertical and horizontal leg of the weld should be reported as a percentage of the total leg length, i.e.,

$$\frac{(V_c + H_c)}{V + H} \times 100 = \text{cracking index}$$

where

$V$ = Vertical leg length, in.
$H$ = Horizontal leg length, in.
$V_c$ = Length of crack in vertical leg.
$H_c$ = Length of crack in horizontal leg.

The severity of any *weld* cracking present should also be noted.

### General Note

In the proposed test program the electrodes to be used are X (10 g) and Y (8 and 6 g).

To ensure that the heat input to the test piece is controlled, Table 8 has been drawn up giving suggested amperages for the test runs. It is appreciated that the amperage selected will depend to a large extent on the welding equipment available, and the values specified below are for guidance only.

Table 8—Amperages

| *Electrode* | *Gage* | *Amp* |
|---|---|---|
| X | 10 | 115 |
| Y | 8 | 155 |
| Y | 6 | 200 |

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J. Imperati and R. F. Pulver, Welding Engineers
The American Brass Company, Waterbury, Conn.

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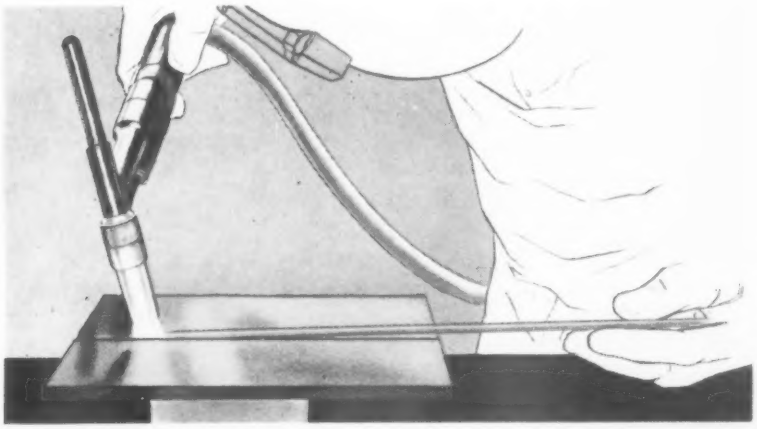

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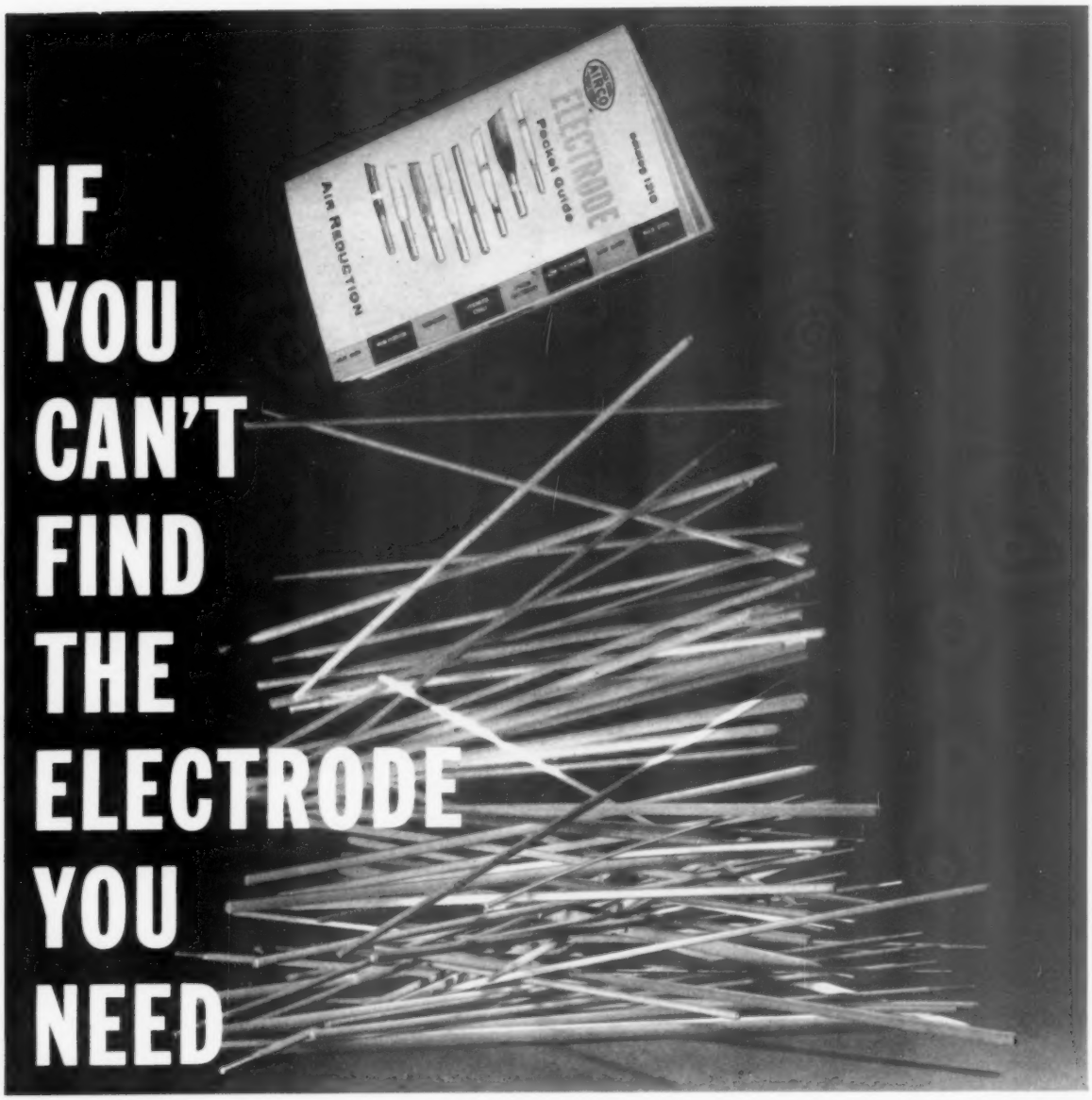


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